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THE SCIENTIFIC MONTHLY

MARCH, 1921

THE BIOLOGY OF DEATH: I—THE PROBLEM[1]

By Professor RAYMOND PEARL

THE JOHNS HOPKINS UNIVERSITY

1. Introduction

PROBABLY no subject so deeply interests human beings as that of the duration of human life. Presumably just because the business of living was such a wonderfully interesting and important one from the viewpoint of the individual, man has endeavored, in every way he could think of, to prolong it as much as possible. He has had recourse to both natural and supernatural schemes for attaining this objective. On the mundane plane he has developed the sciences and arts of biology, medicine and hygiene, with the fundamental purpose of stretching the length of each individual's life on earth to the greatest attainable degree. Recognizing pragmatically, however, that at best the limitations in this direction were distinctly narrow, when conceived in any historical sense, he has with singularly wide-spread unanimity, deemed it wise to lay a hedging bet upon a horse of another color. Man's body plainly and palpably returns to dust, after the briefest of intervals, measured in terms of cosmic evolution. But there is nothing in this fact which precludes the postulation of an infinite continuation of that impalpable portion of man's being which is called the soul. With the field thus open we see some sort of notion of immortality incorporated in an integral part of almost all folk philosophies of which any record exists.

Now, perhaps unfortunately, perhaps fortunately, it has up to the present time proved impossible absolutely to demonstrate, for reasons which will presently appear, by any scientifically valid method of experimentation or reasoning, that any real portion of that totality of being which is an individual living man persists after he dies. Equally, for the same reasons, science can not absolutely demonstrate that such per-

[1] Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 28.

This, and the papers which will follow it under the same general title are based upon a series of lectures recently given at the Lowell Institute in Boston.

sistence does not occur. The latter fact has had two important consequences. In the first place, it has permitted many millions of people to derive a real comfort of soul in sorrow, and a fairly abiding tranquility of mind in general from the *belief* that immortality is a reality. Even the most cynical of scoffers can find little fault with such a result, the world and human nature being constituted as they are. The other consequence of science's present inability to lay bare, in final and irrefragable terms, the truth about the course, if any, of events subsequent to death is more serious. It opens the way for recurring mental epidemics of that intimate mixture of hyper-credulity, hyper-knavery, and unsatisfied Freudian urges, which used to be called spiritualism, but now usually prefers more seductive titles. We are at the moment in the midst of perhaps the most violent and destructive epidemic of this sort which has ever occurred. Its evil lies in the fact that in exact proportion to its virulence it destroys the confidence of the collective mind of humanity in the enduring efficacy of the only thing which the history of mankind has demonstrated to contribute to the real advancement of his intellectual, physical, spiritual and moral well being, namely that orderly progression of ascertained knowledge which we now call *science*.

The reason why science finds itself helpless to prevent spiritualism's insidious sapping of the intellectual fiber of the race is because it is asked to prove a negative, upon the basis of unreal data. How difficult such a task is is obvious as it is proverbial. Until science has demonstrated that there is *not* a continuation of individual supernatural existence after natural death, the spiritualist can, and will, come forward with supposed demonstrations that there is such a continuation. But the most characteristic feature of science is its actuality, its reality, its naturality. Pearson has pointed out, in characteristically clear and vigorous language, the reason why, in the minds of uninformed persons, science appears helpless in this situation. He says:

> Scientific ignorance may either arise from an insufficient classification of facts, or be due to the unreality of the facts with which science has been called upon to deal. Let us take, for example, fields of thought which were very prominent in medieval times, such as alchemy, astrology, witchcraft. In the fifteenth century nobody doubted the "facts" of astrology and witchcraft. Men were ignorant as to how the stars exerted their influence for good or ill; they did not know the exact mechanical process by which all the milk in a village was turned blue by a witch. But for them it was nevertheless a fact that the stars did influence human lives, and a fact that the witch had the power of turning the milk blue. Have we solved the problems of astrology and witchcraft today?
>
> Do we now know how the stars influence human lives, or how witches turn milk blue? Not in the least. We have learnt to look upon the facts themselves as unreal, as vain imaginings of the untrained human mind; we have learnt that they could not be described scientifically because they involved notions which were in themselves contradictory and absurd. With alchemy the case was somewhat different. Here a false classification of real facts was combined with inconsistent sequences—that is, sequences not deduced by a rational method. So soon as science entered the field of alchemy with a true classification and a true method, alchemy was converted into

chemistry and became an important branch of human knowledge. Now it will, I think, be found that the fields of inquiry, where science has not yet penetrated and where the scientist still confesses ignorance, are very like alchemy, astrology, and witchcraft of the Middle Ages. Either they involve facts which are in themselves unreal—conceptions which are self-contradictory and absurd, and therefore incapable of analysis by the scientific or any other method—or, on the other hand, our ignorance arises from an inadequate classification and a neglect of scientific method.

This is the actual state of the case with those mental and spiritual phenomena which are said to lie outside the proper scope of science, or which appear to be disregarded by scientific men. No better example can be taken than the range of phenomena which are entitled Spiritualism. Here science is asked to analyse a series of facts which are to a great extent unreal, which arise from the vain imaginings of untrained minds and from atavistic tendencies to superstition. So far as the facts are of this character, no account can be given of them, because, like the witch's supernatural capacity, their unreality will be found at bottom to make them self-contradictory. Combined, however, with the unreal series of facts are probably others, connected with hypnotic and other conditions, which are real and only incomprehensible because there is as yet scarcely any intelligent classification or true application of scientific method. The former class of facts will, like astrology, never be reduced to law, but will one day be recognized as absurd; the other, like alchemy, may grow step by step into an important branch of science. Whenever, therefore, we are tempted to desert the scientific method of seeking truth, whenever the silence of science suggests that some other gateway must be sought to knowledge, let us inquire first whether the elements of the problem, of whose solution we are ignorant, may not after all, like the facts of witchcraft, arise from a superstition, and be self-contradictory and incomprehensible because they are unreal.

Let us recapitulate briefly our discussion to this point. Mankind has endeavored to prolong the individual life by natural and by supernatural means. This latter plan falls outside the present purview of the scientific method. The former is, in last analysis, responsible for the development of the science of biology, pure and applied, and the arts which found their operations upon it. Biology can and has contributed much to our knowledge of natural death and the causes which determine the duration of life. It is the purpose of this series of lectures to review this phase of biological science, and endeavor to set forth in an orderly and consistent manner the present state of knowledge of the subject.

2. The Problem

The problem of natural death has two aspects, one general, the other special. These may be stated in this way:

1. Why do living things die? What is the meaning of death in the general philosophy of biology?

2. Why do living things die *when* they do? What factors determine the duration of life in general and in particular, and what is the relative influence of each of these factors in producing the observed result?

Both of these problems have been the subject of much speculation and discussion. There has accumulated, especially in recent years, a considerable amount of new experimental and statistical data bearing upon them. I hope to be able in what follows to show that this new

material, together with that which has for a long time been a part of the common store of biological knowledge, makes possible a clearer and more logically consistent picture than we have had of the meaning of death and the determination of longevity. Let us first examine in brief review the broad generalizations about death which have grown up in the course of the development of biology, and which may now be regarded as agreed to by practically all biologists.

3. Biological Generalizations About Natural Death

The significant general facts which are known about natural death are these:

(a). *There is an enormous variation in the duration of life, both intra and inter-racially.* Table 1, which is adapted from various authorities, is to be read with the understanding that the figures are estimates frequently based upon somewhat general and inexact evidence, and record extreme, though it is believed authentic instances. While the figures, on the accounts which have been mentioned, are subject to large probable errors, the table does give a sufficiently reliable general picture of the truth to indicate the enormous differences which exist among different forms of animal life in respect of longevity.

TABLE 1

Longevity of Animals

Animal	Approximate limits of maximum duration of life in different species
Lower invertebrates	24 hours to?
Insects	24 hours to 17 years
Fish	? to 267 years
Amphibia	? to 36 years
Reptiles	? to 175 years
Birds	9 years to 118 years
Mammals	1½ years to over 100 years

We see from this table that life may endure in different forms from only the briefest period, measured in hours as in the case of *Ephemeridae*, to somewhere in the hundreds of years. The extremely long durations are of course to be looked upon with caution and reservation, but if we accept only extreme cases of known duration of life in man, the range of variation in this characteristic of living things is sufficiently wide.

It is probable that man, in exceptional instances, is nearly the longest lived of all mammals. The common idea that whales and elephants attain great longevity appears not to be well founded. The absolutely authentic instances of human survival beyond a century are, contrary to the prevalent view and customary statistics, extremely rare. The most painstaking and accurate investigation of the frequency of occurrence of centenarians which has ever been made is that of T. E.

Young. Because of the considerable intrinsic interest of the matter, and the popular misconceptions which generally prevail about it, it will be worth while to take a little time to examine Young's methods and results. He points out in the beginning that the evidence of great age which is usually accepted by census officials, by registrars of death, by newspaper reporters, and by the general public, is, generally speaking, of no validity or trustworthiness whatever. Statements of the person concerned, or of that person's relatives or friends, as to extreme longevity, can almost invariably be shown by even a little investigation to be extremely unreliable. To be acceptable as scientific evidence, any statement of great age must be supported by unimpeachable *documentary* proof of at least the following points:

a. The date of *birth*, or of baptism.
b. The date of *death*.
c. The *identity* of the person dying at a supposed very advanced age with the person for whom the birth or baptismal record, upon which the claim of great age is based, was made out.
d. In the case particularly of married women the date of *marriage*, the person to whom married, and any other data which will help to establish proof of identity.

In presumptive cases of great longevity, which on other grounds are worthy of serious consideration, it is usually in respect of item c—the proof of identity—that the evidence is weakest. Every student of genealogical data knows how easy it is for the following sort of thing to happen. John Smith was born in the latter half of the eighteenth century. His baptism was duly and properly registered. He unfortunately died at the age of say 15. By an oversight his death was not registered. In the same year that he died another male child was born to the same parents, and given the name John Smith, in commemoration perhaps of his deceased brother. This second John Smith was never baptized. He attained the age of 85 years, and then because of the appearance of extreme senility which he presented, his stated age increased by leaps and bounds. A study of the baptismal records of the town disclosed the apparent fact that he was just 100 years old. The case goes out to the public as an unusually well authenticated case of centenarianism, when of course it is nothing of the sort.

Young applies rigidly the criteria above enumerated first, to the historically recorded cases of great longevity such as Thomas Parr, *et id genus omne*, and rejects them all; and second to the total mortality experience of all the Life Assurance and Annuity Societies of Great Britain and the annuity experience of the National Debt Office. The number of persons included in the experience was close upon a million. He found in this material, and from other outside evidence, exactly 30 persons who lived 100 or more years. In Table 2 the detailed results of his inquiry are shown in condensed form.

TABLE 2
Authentic Instances of Centenarianism (from Young)

Sex	Social status (single or married)	Age at death (or living)		
		Years	Months	Days
♀	M	110	..	321
♀	M	108	..	144
♀	M	105	8	...
♀	S	104	9	16
♀	M	103	9	28
♀	?	103	..	269
♀	M	103	3	7
♂	?	103	1	8
♂	?	102	9	2
♀	?	102	..	218
♀	S	102	2	10
♀	S	102	1	8
♀	S	102	..	21
♀ *	S	102	..	19
♂	?	102	..	2
♀ **	S	101	10	4
♀	S	101	8	25
♂	?	101	..	263
♂	?	101	4	...
♀	S	101	1	16
♀	S	101	1	4
♂	?	101	..	32
♀	S	101	..	1
♂	?	100	9	4
♀	S	100	7	6
♀	S	100	6	9
♀	M	100	..	133
♂	M	100	2	24
♀	S	100	1	10
♂	?	100	..	20

*Living 30 September, 1905.
**Living 31 July, 1898.

It will be noted from this table that the most extreme case of longevity which Young was able to authenticate was about a month and a half short of 111 years. Of the 30 centenarians recorded 21 were women and 9 were men. The superiority of women in expectation of life is strikingly apparent at the very high age of 100 years. We shall later see that this is merely a particularly noteworthy instance of a phenomenon which is common to a great portion of the life span.

The contrast between these proved findings of Young exceedingly modest both in respect of numbers and extremity of longevity, and the loose data on centenarianism which one can find in any year's mortarity statistics, is striking. In an examination of the matter recently I found that in the Registration area of the United States there were recorded in the year 1916, out of a total of 1,001,921 deaths at all ages the following as of ages 100 or over.

White males	137
Colored males	116
White females	180
Colored females	216
Total	649

In this large total 4 persons were recorded as having died at age 120, and one, a colored female, at the preposterous age of 134!

B. *There is no generally valid, orderly relationship between the average duration of life of the individuals composing a species and any other broad fact now known in their life history, or their structure, or their physiology.* Many attempts have been made to set up generalizations establishing connections of this sort. Weismann particularly has endeavored to establish such relations only to have them overthrown sometimes by facts which he himself presents. It has, for example, been contended that the larger an animal the longer its life. This is obviously no general law. Again it has been held that no animal lives after reproducing, except such as care for their young, but almost numberless instances can be adduced where no such relationship holds. It will not pay us to examine all the hypotheses of this general type which have, at one time or another, been put forward. With one exception, to which we shall advert immediately, they all suffer from too many important exceptions to be considered valid generalizations.

C. *Natural death as distinguished from accidental death is preceded by definite structural and functional changes in the body.* These changes in the structure of different organs and parts of the body, and in their manner of functioning constitute the material basis of what is called *senescence* or growing old. Some of the morphological and physiological changes which characterize extreme senescence are apparent and known to all. Such are in case of man the bent posture which means a bending and fusion of the elements of the vertebral column, the wrinkled visage, which denotes a profound alteration of tissue elements, and the shuffling and uncertain gait, which bespeaks a failing motor coordination. In Figure 1 these senescent changes are all well indicated in the case of an old man who has received much newspaper notice during the past year, "Uncle" John Snell of Kentucky, who is here shown with his last wife and supposed son. This poor old man has been exhibited about that part of the country as "The oldest living human being," at a claimed age of 131 years. As a matter of fact, Nascher, who has made a careful investigation of the case, finds him to be "about one hundred years old, possibly a year younger or older." The paternity of the 4½ year old boy, though claimed by Shell, is in considerable doubt.

Besides these obvious senescent changes there are going on even more significent changes in the cellular elements which compose the body. Certain of these cellular changes of age were fully described, in a brilliant series of Lowell lectures given a little more than a decade ago by a great master of morphological research, the late Dr. Charles Sedgwick Minot. Over a quarter of a century ago Hodge made a careful study of senile changes in nerve cells. In a man dying naturally

at 92 years of age he found marked changes in the cells of the spinal ganglia as compared with those of a new born babe. The chief differences are exhibited in Table 3.

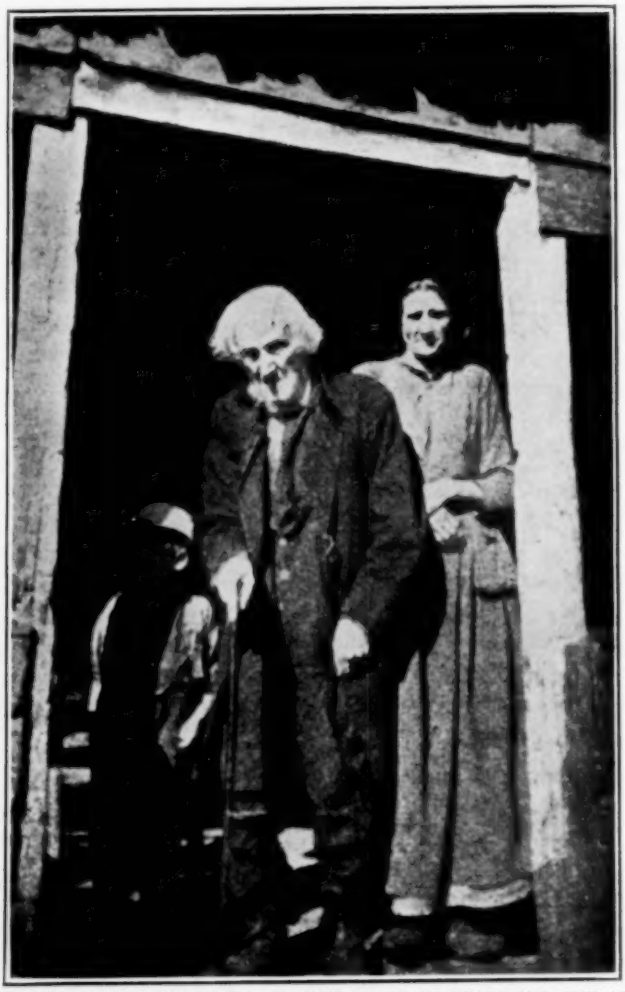

FIG. 1. PHOTOGRAPH OF JOHN SHELL, CLAIMED TO BE 131 YEARS OLD, BUT ACTUALLY ABOUT 100, WITH HIS WIFE AND PUTATIVE SON. (From Nascher).

TABLE 3

Showing the Principal Differences Observed on Comparing the Spinal Ganglion Cells (First Cervical Ganglion) from a Child at Birth With Those from a Man Dying of Old Age at Ninety-two Years.
(From Hodge's data)

	Baby at birth. Male	Old Man
Volume of nucleus	100 per cent.	64.2 per cent.
Nucleoli visible	53 per cent.	5 per cent.
Deep pigmentation	0 per cent.	67 per cent.
Slight pigmentation	0 per cent.	33 per cent.

Hodge found still more marked changes in the antennary lobe of the nervous system of the honey bee. The nature of the changes is shown in Figure 2.

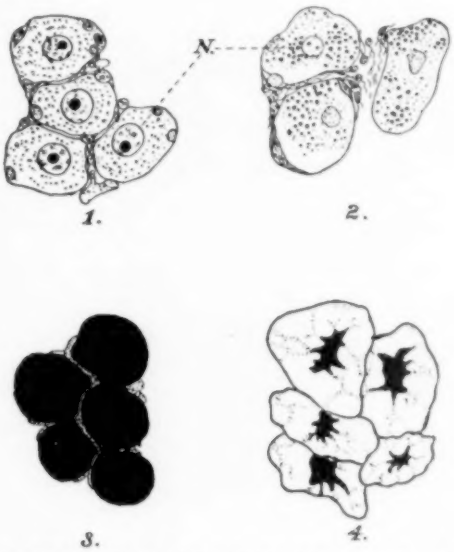

FIG 2. SHOWING THE CHANGES IN NERVE CELLS DUE TO AGE. 1, spinal ganglion cells of a still-born male child; 2, spinal ganglion cells of a man dying at ninety-two years; N, nuclei. In the old man the cells are not large, the cytoplasm is pigmented, the nucleus is small, and the nucleolus much shrunken or absent. Both sections taken from the first cervical ganglion. X 250 diameters; 3, nerve cells from the antennary ganglion of a honey-bee, just emerged in the perfect form; 4, cells from the same locality of an aged honey-bee. In 3, the large nucleus (black) is surrounded by a thin layer of cytoplasm. In 4, the nucleus is stellate, and the cell substance contains large vacuoles with shreds of cytoplasm. (From Donaldson after Hodge).

In the ganglion cells of both man and the honey bee, the volume of the nucleus in proportion to that of the rest of the cell body becomes reduced with advancing age. Dr. Minot showed that this was a very general phenomenon in senescence, and was a continuous process from birth to death. He gave to it and related and associated cellular changes the name "cytomorphosis," and attributed to it the greatest significance in bringing about senescence and death. As we shall presently see, cytomorphosis may perhaps more justly be regarded as one of the morphological results of senescence rather than its cause.

Recently Mrs. Pixell-Goodrich, an English worker, has re-studied the senescent changes in the cells of the honey bee. Her work shows in a striking way the loss of protoplasm in the aged cell. In the young bee immediately after hatching, the cells are large and plump, only separated from each other by narrow strands of connective tissue. In the same region of the same ganglion in an old bee which came from a hive on a fine day in March, but was too weak to effect a cleansing flight and soon became moribund, the nerve cells were quite worn out. There was left only a framework of connecting tissue, with an occasional nucleus of a nerve cell in a more or less necrotic condition, with only a little cytoplasm around it.

There are other, and perhaps even more general and striking morphological changes in senescence than the changed relation between cytoplasm and nucleus. Conklin says:

> By all odds the most important structural peculiarity of senescence is the increase of metaplasm or differentiation products at the expense of the general protoplasm. This change of general protoplasm into products of differentiation and of metabolism is an essential feature of embryonic differentiation and it continues in many types of cells until the entire cell is almost filled with such products. Since nuclei depend upon the general protoplasm for their growth, they also become small in such cells. If this process of the transformation of protoplasm into differentiation products continues long enough it necessarily leads to the death of the cell, since the continued life of the cell depends upon the interaction between the general protoplasm and the nucleus. In cells laden with the products of differentiation, the power of regulation is first lost, then the power of division, and finally the power of assimilation; and this is normally followed by the senescence and death of the cells.

D. *Natural death (as distinguished from accidents) occurs normally and necessarily only in animals composed of many cells.* Unicellular organisms are finally known, chiefly as the result of the brilliant and painstaking researches of Woodruff and his students, to be immortal *in esse* as well as *in posse*. Since the discovery by Woodruff and Erdmann of the process of nuclear reorganization, which they call endomixis, this conclusion is as solidly grounded if we regard a cycle of protozoan divisions as the homologue of the metazoan body, as it is if we consider each individual protozoan as such homologue. Woodruff has been cultivating the common unicellular form *Paramecium*, shown in Figure 3, for over 13 years.

During all this time no conjugation or pairing of individuals has occurred. In a recent letter Dr. Woodruff says: "After we had discovered and worked out endomixis there seemed no particular use of carefully recording the number of generations each day. But the culture is still going on as well as ever and is at approximately the 8500th generation—13½ years old! On May 1st, 1915, (just 8 years old) it was at the 5071st generation." If in 8,500 generations—a duration of healthy reproductive existence which, if the generation were of the same length as in man would represent roughly a quarter of a million years in absolute time,—natural death has not occurred, we may with reasonable assurance conclude that this animal is immortal.

The distinction between Protozoa and Metazoa in respect of the incidence of natural death is so important that it requires a somewhat detailed explanation, together with the reasons for it. Protozoa reproduce by a process of simple division or fission. A particular individual after growing to a certain size simply divides transversely into two like individuals, at first smaller in size, but rapidly growing to full adult magnitude. The essential gross features of this process are illustrated in Figure 4. One can not say which is parent and which is offspring. One individual simply becomes two. Upon occasion another process known as *conjugation* may intervene.

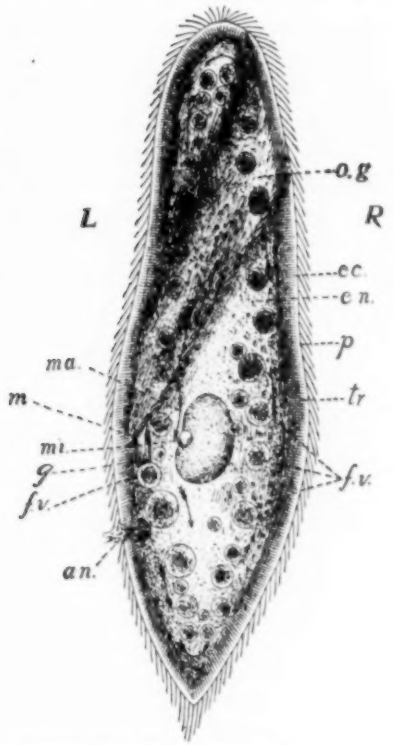

FIG. 3. PARAMECIUM, VIEWED FROM THE ORAL SURFACE. *L*, left side; *R*, right side; *an.*, anus; *ec.*, ectosarc; *en.*, endosarc; *f. v.*, food vacuoles; *g*, gullet; *m*, mouth; *ma.*, macronucleus; *mi.*, micronucleus; *o. g.*, oral groove; *P.*, pellicle; *tr.*, trichocyst layer. The arrows show the direction of movement of the food vacuoles. (From Jennings).

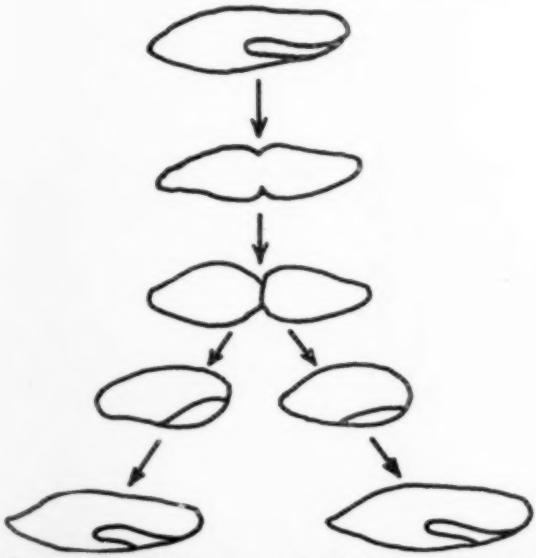

FIG. 4. DIAGRAM SHOWING THE PROCESS OF REPRODUCTION BY FISSION IN THE UNICELLULAR ORGANISM *Paramecium*.

FIG. 5. CONJUGATION IN PARAMECIUM

In this process two individuals mate together. By a process of assortative mating like sizes pair together, as was first shown by the writer and later confirmed by Jennings. After pairing has occurred an interchange of nuclear substance occurs by a complicated mechanism described and figured in many elementary textbooks of zoology. This process of conjugation need not further concern us here, for the reason that Woodruff in the work already referred to has shown that this phenomenon is not essential to the continued life of the race. Its place may be, and normally very frequently is, taken by the process called

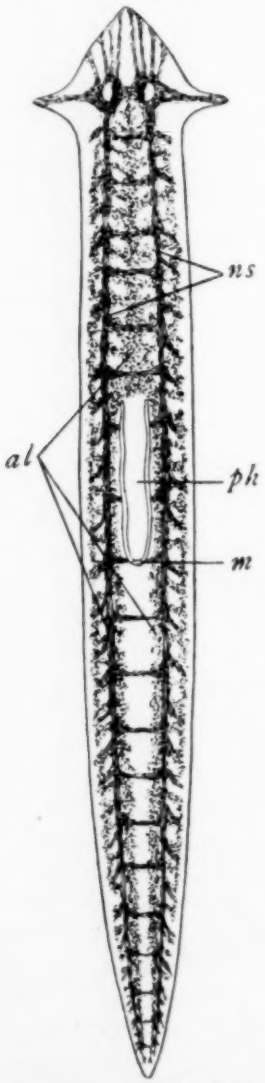

FIG. 6. PLANARIA DOROTOCEPHALA: *m*, mouth; *ph*, pharynx; *al*, alimentary tract; *ns*, nervous system. (From Child).

endomixis. In this process there occurs a nuclear breakdown and reorganization which appears to be the equivalent, functionally at least, of that which takes place during conjugation.

Now it is apparent that there is no place for death in a scheme of reproduction by simple fission such as is illustrated in Figure 4. Nothing is left at any stage to fulfill the proverbial scheme of "dust to dust and ashes to ashes." When an individual is through its single individual existence it simply becomes two individuals, who go merrily on playing the fascinating game of living here and now. There is, in short, no hope that messages will be received from Paramecia in the spirit world, for the simple reason that there is no chance for the soul of a Paramecium—assuming for the argument that he has one—to get there.

In a few of the simplest and most lowly organized groups of many-celled animals or Metazoa this power of multiplication by simple fission, or budding off a portion of the body which reproduces the whole, is retained as a facultative asset. This process of reproduction in which the somatic or body cells of one generation produce the

FIG. 7. BEGINNING OF PROCESS OF AGAMIC REPRODUCTION BY FISSION IN PLANARIA (From Child).

somatic cells of the next generation has been called agamic reproduction. It occurs as the more usual but not exclusive mode of reproduction, in some or all forms of the three lowest groups of multicellular organisms, the sponges, flatworms, and coelenterates. More rarely it may occur in other of the lower invertebrate groups. It may occur in the form of budding or of fission comparable to that of the *Protozoa*. The agamic reproduction of one of the flatworms, *Planaria dorotocephala*, studied by the writer many years ago, shown in Figure 6, may serve as an illustration.

This simply organized worm, which lives under stones in sluggish streams and ponds, after attaining a certain size, will under the appropriate environmental conditions exhibit a constriction towards the posterior end of the body, as shown in Figure 7.

For a time the animal moves about as a rather ungainly double individual. It finally separates into two. The larger anterior part forms a new tail, and the smaller posterior fission product forms a new head and rapidly grows to full size. The process is in principle exactly the same as the multiplication of Paramecium by fission. In another member of the same general group of animals as *Planaria*, named *Stenostomum*, several fission planes may form and the process start anew before the products delimited by the first plane have separated. As a result we get frequently in this form chains of individuals attached in a long string to each other, as shown in Figure 8.

It is obvious that so long as reproduction goes on in this manner in these multicellular forms there is no place for death. In the passage from one generation to the next no residue is left behind. Agamic reproduction, and its associated absence of death occurs very commonly in plants. Budding and propagation by cuttings are the common forms in which it is seen. The somatic cells have the capacity of continuing multiplication and life for an indefinite duration of time, so long as they are not accidentally caught in the breakdown and death of the whole individual in which they are at the moment located. Thus virtually every apple tree in every orchard in this country is simply a developed branch or bud of some original apple tree from which it was cut, in many cases centuries ago. Apple trees can not of their own unaided efforts propagate either buds or cuttings. So until the intervention of man apple trees died natural deaths, somatically speaking, just as do the higher animals of which we shall speak presently. But their cells were inherently capable of better things, as was demonstrated when man first cut off a shoot from an old apple tree and provided it with a root by grafting.[2] Then it went on and made a new tree. From it in turn cuttings were taken, and so the process has continued to the present day. A part of the soma of one generation produces the soma of the next generation and goes on living indefinitely.

A different mode of reproduction is characteristic of higher multicellular animals, and in all but the lowest groups is the exclusive method. A new individual is started by the union of two peculiar cells of extraordinary potentialities, called germ cells. These germ cells are of two sorts, ova and spermatozoa. In bisexual organisms the former are borne in the female, and the latter in the male body. Both sorts undergo a complicated preparation for union, the result of which is that when union does occur each party to it contributes either an exactly equal or an approximately equal amount of hereditary material. After union has taken place the fertilized ovum or zygote

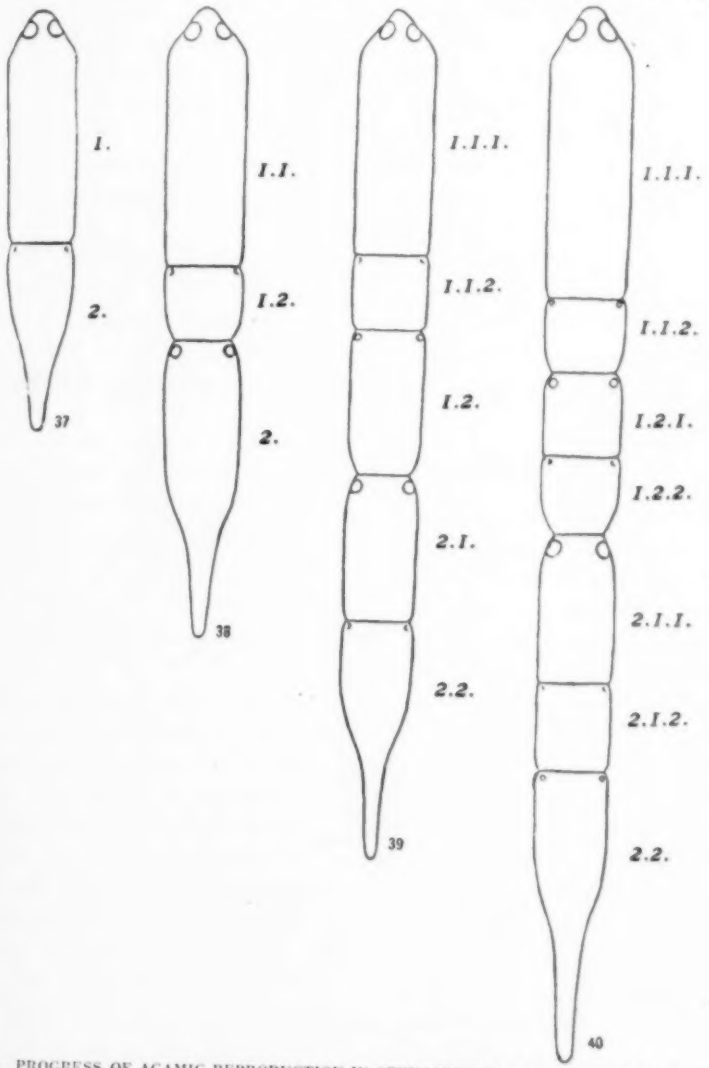

FIG. 8. PROGRESS OF AGAMIC REPRODUCTION IN STENOSTOMUM: the sequence in the formation of new zooids is indicated by the numerals. (From Child).

presently begins to divide, first into two cells, these again to four, and so on until by a continuation of this process of division with concomitant differentiation the whole body is formed. As the animal develops by repeated cell division and differentiation it is frequently found that at a very early stage the cells which are to be the germ cells of the next generation are clearly recognizable by their structure, and often are set aside in a definite location in the developing embryo. Thus, to take out a single example of phenomenon of wide generality, at a very early stage in the development of the dog-fish, when the only bodily organs of which even the rudiments are recognizable are the beginnings of what will presently become the spinal cord and the backbone, it was shown by Woods many years ago that the germ cells are definitely localized and recognizable, as shown in Figure 9.

In some forms, notably the round-worm *Ascaris*, various crustacea and insects, the cells which are to become germ cells are visibly set apart from the very first or one of the first three or four cleavages of the fertilized ovum. For example, in the case of the crustacean *Cyclops* Amma has shown that the granules visible at one pole in the very first division mark the prospective germ path, as shown in Figure 10.

In the gnat *Chironomus* the same thing is visible at a very early cleavage, according to the observations of Harper. For the most comprehensive and critical review in existence of the extensive literature on the *Keimbahn* one should consult the recent contributions of Hegner on the subject.

To condense a long and complicated matter we may state the situation regarding reproduction and death in the *Metazoa* in this way. A higher, multicellular individual may be conceived, from the viewpoint of the present discussion, as composed of two essentially independent portions, the germ cells on the one hand, which are immortal in the same sense that the Protozoa are immortal, and the rest of the body, which it is convenient to call technically the soma, on the other hand. The soma undergoes natural death after an interval of time which as we have seen varies from species to species. The germ cells which the individual bears in its body at the time of its death of course die also. But this is purely accidental death so far as concerns the germ cells. Such of them as were, prior to the death of the soma, enabled to unite with other germ cells went on living just as does the dividing *Paramecium*. Reduced to a formula we may say that the fertilized ovum (united germ cells) produces a soma, and more germ cells. The soma eventually dies. Some of the germ cells, prior to that event produce somata and more germ cells, which in turn produce somata and germ cells, and so on in a continuous cycle which has never yet ended since the appearance of multicellular organisms on the earth.

[2]This provision of roots was not essential, only practically convenient. The cutting would, if enough pains were taken, grow its own roots.

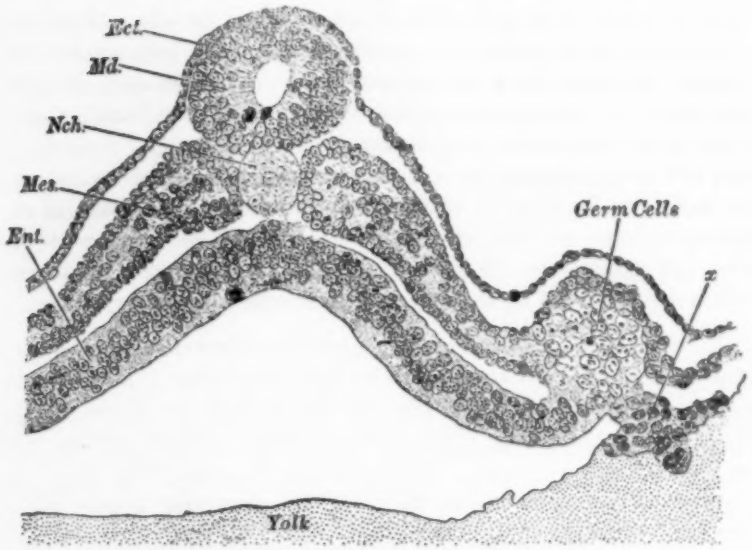

FIG. 9. SECTION ACROSS THE POSTERIOR PART OF AN EMBRYO DOG-FISH (ACANTHIAS) OF 3.5 MM., to show the compact cluster of germ cells on one side. The germ cells in later stages migrate from this primitive position, moving singly or in small groups. *Ect*, ectoderm; *Md*, medullary canal or primitive spinal cord; *Nch*, notochord; *Mes*, mesoderm; *Ent*, entoderm; *X*, cellular strand connecting the germ cell cluster with the yolk. (From Minot after Woods, with permission of the publishers, G. P. Putnam's Sons).

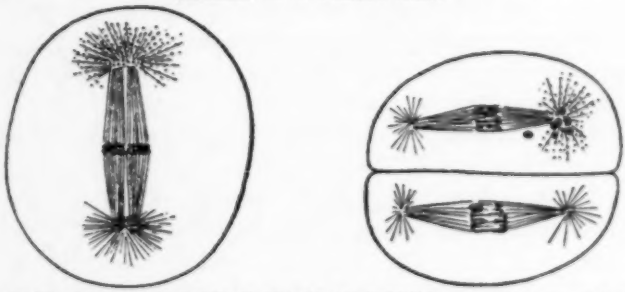

FIG. 10. FIRST AND SECOND DIVISION IN EGG OF CYCLOPS, showing at one pole of spindle the granules which mark the germ path. (From Child, after Amma, by permission of University of Chicago Press).

The contrast between the protozoan and the metazoan method of descent is shown in Figure 11, which is a modification of a similar diagram originally due to my colleague, Dr. H. S. Jennings.

The diagram represents the descent of generations. The upper portion of the diagram shows the mode of descent in forms reproducing from organisms reproducing from a single parent. The lower, or B portion of the diagram shows the mode of descent in form reproducing from two parents. The lines represent the lives of individuals (as in A diagram) or of germ cells (in the B diagram) beginning at the left and passing to the right. In the A diagram which represents uniparental reproduction by fission the line of ancestry traced back from any individual at the right is always single, and there is no corpse to be

found anywhere, each present body transforming directly into the two bodies of the next generation. In the B diagram where we have biparental reproduction by the union of germ cells, as in man, the solid black triangles represent the bodies, or somata, and the lines the germ cells. A line of ancestry traced back from any individual towards the right end of the diagram forks at each generation, and in comparatively few generations one has a multitude of ancestors. The *bodies* of one generation have no continuity with the bodies of the previous or the following generation. In each generation the soma dies while new somata are produced by the union of germ cells from diverse lines.

E. *Life itself is a continuum.* A break or discontinuity in its progression has never occurred since its first appearance. Discontinuity of existence appertains not to life, but only to one part of the makeup of a portion of one large class of living things. This is certain, from the facts already presented. Natural death is a new thing which has appeared in the course of evolution, and its appearance is concomitant with, and evidently in a broad sense, caused by that relatively early evolutionary specialization which set apart and differentiated certain

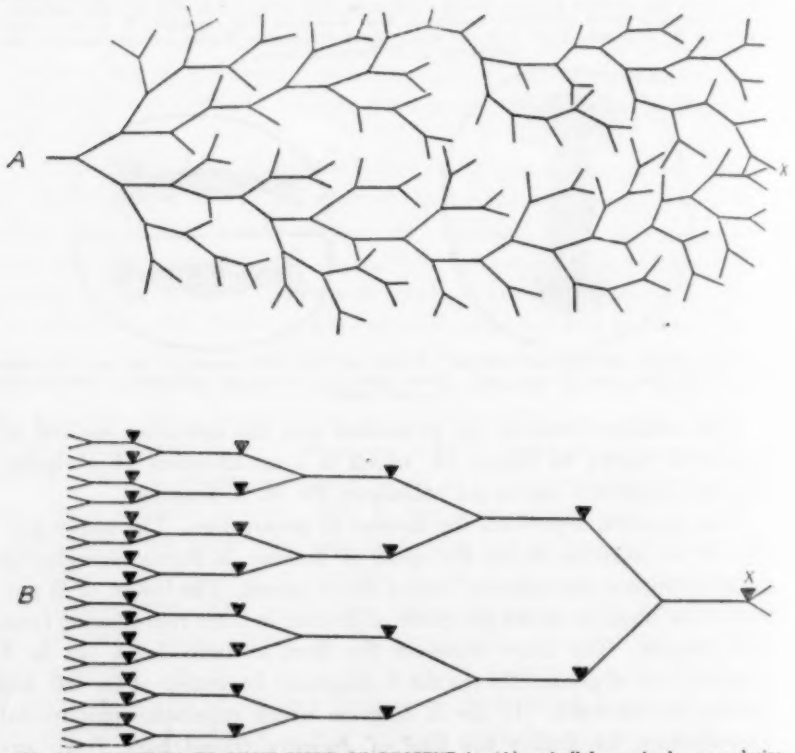

FIG. 11. DIAGRAM TO SHOW MODE OF DESCENT in (A) unicellular animals reproducing agamically, and in (B) multicellular animals reproducing by germ cells. For further explanation see text. (Modified from Jennings).

cells of the organism for the exclusive business of carrying on all functions of the body other than reproduction. We are able to free ourselves, once and for all, of the notion that death is a necessary attribute or inevitable consequence of life. It is nothing of the sort. Life can and does all the time go on without death. The somatic death of higher multicellular organisms is simply the price we pay for the privilege of enjoying those higher differentiations of structure and function which have been added on as a side line to the main business of living things, which is to pass on in unbroken continuity the never-dimmed fire of life itself.

4. Theories of Death

On the basis of these five general classes of facts which have been briefly reviewed a whole series of speculations as to the meaning of death have been reared. Of course, theologians have not failed to assay the ore of so valuable a lode. The one interesting thing to note in passing is that the traditional view which the Christian religion takes of death, is in one important respect in complete accord with the results of modern biology. I refer to the recognition that death is not a *necessary* adjunct or "grand characteristic of life itself." In the view of the Church death is a consequence of sin, and prior to the advent of sin living things were in order to continue indefinitely in the enjoyment of life. Now in this statement what the theologian calls sin the biologist calls differentiation. A wonderful sermon could be preached on this identity of sin and differentiation. It has, of course, always been recognized that the sinful was different. Consideration of the matter convinces one immediately that all too frequently in man's sad history here below the different has been regarded as sinful. But as the object of this discussion is not theological I refrain from pursuing further so alluring a theme.

The first attempt at a biological evaluation[3] of the meaning of death which attracted the serious attention of scientific men was that of Weismann. In his famous address of 1881 on the duration of life, Weismann propounded the thesis that death was an adaptation, advantageous to the race, and had arisen and was preserved by natural selection. Probably no more ridicuously absurd and perverse extension of the theory of natural selection than this was ever made. It appeared, however, just at the time when the post-Darwinian attempt to settle the problems of evolution by sheer dialectic was at the zenith of its popularity. Now-a-day such a doctrine as Weismann's would not receive so respectful a hearing.

Metchnikoff, whose views excited so much popular interest some years ago, held that death was the result of intoxication, arising from the absorption of putrefactive products of the activity of intestinal

bacteria. For obvious reasons such a view has no general validity and does not touch the philosophical problem of the biological meaning of death. More philosophic developments of the same basic idea have been presented by Jickeli and Montgomery. Both held that because of the mechanical incompleteness of the processes of cellular metabolism injurious and toxic substances tend to accumulate in the cells of the body and that senescence and death are the results of such accumulations.

A much broader, and in the light of all the facts sounder view, is that the determination of degrees of longevity and of the fact of death itself, is inherent in the biological constitution of the individual and the species. This view was expressed by Johannes Müller a quarter of a century ago in his *Physiologie*, by Cohnheim forty years later, and has had many later adherents. I shall return to a discussion of it later.

There have been a number of theories of senescence and death, differing widely in details, but having the one point in common of attributing these phenomena to orderly changes with advancing age in the relative proportion of nucleus to cytoplasm in the cells of the body. Here may be mentioned, without pausing to go into detailed consideration of their different views Verworn, Mühlmann, Richard Hertwig, and Minot.

Another group of hypotheses, all advanced in comparatively recent times and associated with the names of Kassowitz, Conklin, and Child, are developed about the metabolic aspects of age changes. There is observed a decrease in assimilatory capacities of cells with differentiation and age. These metabolic changes are regarded as fundamentally causal of the phenomena of senescence and death. In this general group of hypotheses would belong the views of my colleague, Dr. W. T. Howard.

Benedict in a detailed investigation of senility in plants reaches the conclusion

> "that the duration of life is directly linked with the degree of permeability in that part of the living cell which places it in contact with the universe about it, and that as the activities of life proceed the cell is being gradually entombed by an inevitable decrease in the permeability of its protoplasm.
>
> While decreasing permeability furnishes a possible explanation of the more obvious symptoms of senility, it cannot be the only degeneration of first rank. All protoplasmic functions must be involved. Underlying these primary causes of senile degeneration there must be some general fundamental cause from which they spring. This fundamental cause may well be the colloidal nature of protoplasm."

Delage and Jennings have considered that death is the result of differentiation. Unicellular organisms, as we have seen, do not nor-

[3]The following brief review of the various biological hypotheses which have been advanced as to the meaning of death is largely based upon and follows the excellent discussion of the matter given by Child in his "Senescence and Rejuvenescence."

mally experience natural death. In the higher organisms there has been a progressive setting apart of cells and tissues to perform *particular* vital functions with a consequent loss of the ability to perform *all* vital functions independently. As soon as any one of these cells or tissues begins for any cause whatever to fail to perform its special function properly it upsets the delicate balance of the whole associated community of cells and tissues. Because of the differentiation and specialization of function the parts are mutually dependent upon each other to keep themselves and the whole going. Consequently any disturbance in the balance which is not promptly righted by some regulatory process must eventually end in death. Essentially this view of the matter has been well set forth by Loeb in his most recent paper on the subject. He says: "All this points to the idea that death is not inherent in the individual cell, but is only the fate of more complicated organisms in which different types of cells or tissues are dependent upon each other. In this case it seems to happen that one or certain types of cells produce a substance or substances which gradually become harmful to a vital organ like the respiratory center of the medulla, or that certain tissues consume or destroy substances which are needed for the life of some vital organ. The mischief of death of complex organisms may then be traced to the activity of a black sheep in the society of tissues and organs which constitute a complicated multicellular organism."

At this point I shall not stay to discuss critically each of the hypotheses so summarily reviewed. Instead I shall make bold to state somewhat categorically my own views on the origin and meaning of death and the determination of longevity, and in what follows shall endeavor to set forth in orderly array the evidence which seems to me to support these views. In this process the relations to the conclusions of earlier investigators of what I shall suggest will, I think, sufficiently appear.

Let us consider, then, the following picture of life and death.

1. Life itself is inherently continuous.

2. Living things, whether single-celled or many-celled organisms, are essentially only physico-chemical machines of extraordinary complexity, but regardless of their degree of complexity only amenable to, and activated in accordance with, physical and chemical laws and principles.

3 The discontinuity of death is not a necessary or inherent adjunct or consequence of life, but is a relative new phenomenon, which appeared only when and because differentiation of structure and function appeared in the course of evolution.

4. Death necessarily occurs only in such somata of multicellular organisms as have lost through differentiation the power of reproducing the whole soma from a part of it, or still possessing such power in their cells, have lost the necessary mechanism for separating a part of the soma from the rest for purposes of agamic reproduction.

5. Somatic death results from an organic disharmony of the whole organism, initiated by the failure of some organ or part to continue in its normal harmonious functioning in the entire differentiated and mutually dependent system. This functional breakdown of a part may be caused in a multitude of ways from external or internal sources. It may manifest itself in a great variety of ways both structurally and functionally. Many of these manifestations which have been regarded as causes of senescence, may more truly be considered concomitant attributes of senescence.

6. As a consequence of our second thesis which postulated life to be a mechanism, death, whether of a single somatic cell or of a whole soma, is a result of physico-chemical changes in the cell or organism and these changes are in accordance with ordinary physico-chemical laws and principles

7. The time at which natural death of the soma occurs is determined by the combined action of heredity and environment. For each organism there is a specific longevity determined by its inherited physico-chemical constitution. This specific longevity is capable of modification, within relatively narrow limits, as a result of the impact of environmental forces, the chief mode of action of the environment being in the direction of determining the rate at which the inherited endowment is used up.

For no one of the separate elements of this picture can I claim any particular originality. Most of them would probably be agreed to at once, at least by some biologists. The need is for a synthesizing into a consistent whole of a wide range of data which have accumulated in various fields of biology about death and the duration of life. Such a synthesis will be attempted in what follows. Generally those who have speculated about the biology of death have drawn their evidence from, or at least had their thinking largely colored by the facts in a relatively small part of the whole field. In particular few biologists have any detailed knowledge of the most impressive mass of material, both in respect of quality and quantity, which exists regarding the duration of life of any organism. I refer, of course, to the enormous volume of rather exact data regarding human mortality. Much of this material, to be sure, wants proper analysis, not only mathematical but biological. But that it is a rich material admits of no doubt.

HAIR COLORATION IN ANIMALS

By Dr. LEON AUGUSTUS HAUSMAN
CORNELL UNIVERSITY

IN some recent papers[1] the writer has endeavored to point out that an accurate knowledge of the histology of mammalian hair may be applicable not alone in the field of pure zoological science, but also in the standardization of furs and fabrics in the industries. The need of some sure means for the identification of textile and fur materials, and for their standardization, is increasingly recognized. The methods of identification which will prove most useful will be those which can be applied, with results of unimpeachable certainty, to any textiles, furs, or fur products, no matter how great a degree of modification away from their original color or texture they may have undergone. In the papers already referred to, attention is called to certain microscopic elements in the structure of the hair shaft which are of value in determining the species of mammal from which the hair was taken. These structural elements are the medulla, or central column of "pith" cells, and the cuticular scales, forming the outermost investiture of the hair shaft. (Fig. 1). The writer has suggested[2] that the pigment granules in the hair shaft, to which the color of the hair is primarily due, may also be used as determinative criteria for identification, when considered either alone or in conjunction with the other compositional units of the hair shaft structure. This paper will strive to show how the nature of the pigment granules in the hair shaft can be used in aiding in the identification of hairs. Detailed criteria of this sort may be useful in making determinations of very small fragments.

The various colors of animal hairs are due either to pigment materials within the shaft, or coloring matter deposited on the outside of the cuticle, and may be modified by the way in which light is reflected from the surfaces of the various structures of the hair shaft itself. Hair which owes its hue to the latter cause is comparatively rare, being found, for example, on the flanks and base of the tail in members of the weasel tribe, and appearing as a yellow tint, from deposits from skin glands. In the great majority of cases, however, it is the presence of pigment *within* the hair shaft which gives color to the hair.

[1]Hausman, L. A., The Microscopic Identification of Commercial Fur Hairs, Sci. Mon., Vol. 10, Jan., 1920, p. 70; Hairs That Make Fabrics, Sci. Am., Feb. 21, 1920, p. 184; Structural Characteristics of the Hair of Mammals, Am. Nat., Vol. 44, Nov.-Dec. 1920, p. 496.

[2]Hausman, L. A., Mammal Fur Under the Microscope, Nat. Hist. (Jour. of Am. Mus. Nat. Hist.) Vol. 20, No. 4, 1920, p. 434.

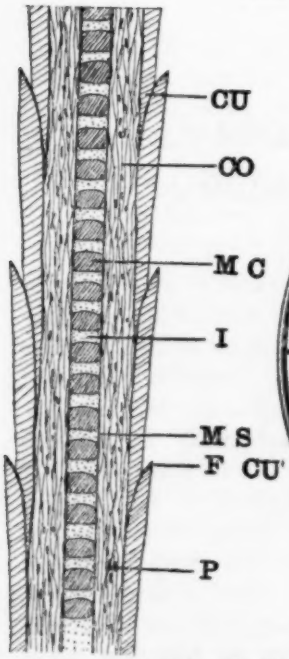

FIG. 1.—Ideal longitudinal section through a generalized mammal hair, CU. cuticular scale, CO. cortex, MC. medullary cells, I. interspaces between medullary cells, MS. medullary shaft, or column, F. CU. free edge of cuticular scale, P. pigment granules in cortex.

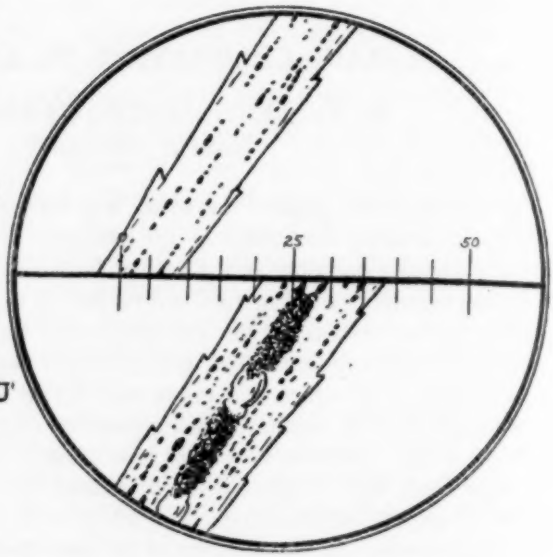

FIG. 2.—Fur hairs from the American otter (above), and the coypu, or "nutria" (below), seen in the comparison ocular. The scale in the center is that of the micrometer eyepiece. Each division equals 5 microns. One micron equals about 1/125,000 of an inch.

The pigment material within the hair shaft may be diffuse *i. e.*, not present in the form of distinct masses, and, if such is the case, the whole shaft is homogeneously stained, and the hair appears, even under the highest powers of the microscope, as a uniformly colored structure. Yellow, or amber hairs are usually pigmented in this way.

The most common cause of color in hair, however, is not external deposit, or internal diffuse stain, but the presence of pigment masses, occurring (1) in the cortex as separate granules, or (2) in the medulla, usually as amorphous masses, though sometimes as discrete granules. Fig. 1 shows a generalized mammal hair, to make clear the relationship of the structures, medulla, cortex, and cuticle.

The hair of the polar bear (Fig. 3) may be taken as typical of a pure white, i. e., colorless, hair. It will be seen that no pigment is present in the cortex of such a hair, which appears under the microscope as a transparent, glassy shaft. The medulla appears to be dark in color. This is due, possibly, to a slight amount of black pigment in the fused medullary cells, but more largely to the dispersion of light from the microscope mirror.

The addition of black pigment in the medulla, very commonly in the form of lenticular masses between the medullary cells, produces hairs of varying shades of gray, a common fur color among mammals. Fig. 5 illustrates the nature of the pigmentation in a hair of typical gray color, the drawing being made from near the middle of the fur hair[3] of the large blarina. An increase in the size of these medullary pigment masses gives to the hair a darker gray color, as illustrated in the hair of the Sewellel, Fig. 6. The size, mode of placentation and especially the form of the medullary pigment masses are in most cases characteristic of the species possessing them, and can be used as valuable aids in identifying hair samples. Gray hair, produced by these lenticular medullary pigment masses, is extremely common among the moles, shrews, voles and soft-fur bearing animals.

Brown pigment masses, composed of granules more or less perfectly fused, are also found between the medullary cells of certain hairs, imparting brown colors, as, for example, in the hair of the cottontail rabbit, Fig. 12. The intensity of the color varies according to the size of the medullary masses, and the depth of color of the component granules. Hairs colored in this way may vary from a light yellowish to a deep reddish brown. Hairs are occasionally found possessing granules in the medulla separate, and not fused. When such is the case the granules are grouped into aggregations of characteristic form and size. Such a condition is illustrated near the base of the fur-or underhair of the muskrat. (Fig. 18).

In a few cases the medullary pigments are also present in the form of separate granules, which are scattered about among the cells of the medulla in a rather uniform way. This gives a pigmentation character quite different from those already mentioned. These granules seem to be largely black, or of various shades of brown. Typical examples of such very distinctive pigmentation characters may be seen in the gray fur hairs of the Sennett kangaroo rat (Fig. 7), in the yellowish-brown hairs of the prairie dog (Fig. 11), and in the yellow hairs of the domestic guinea pig (Fig. 14).

The pigment materials found in the cortex of the hair are usually present in the form of disjunct granules, and are less often coalesced into masses than in the medulla. Furthermore, their patterns of arrangement are all built up along an axis parallel to the hair shaft. This is because the granules are deposited in and among the elongate, fusiform cells, or hair spindles, that go to make up the cortex. (See Fig. 1, CO.). The colors caused by the presence of cortical granules are the various shades of yellows, browns, reds, etc., to black, depending on the depth of color of the granules, and their numbers. The hair

[3]Two varieties of hair occur commonly in mammals: the *fur*, or *under*-hair, usually soft and thick; and the *protective*, or *over*-hair, longer, and stiffer. In the make-up of many furs the protective hair is removed.

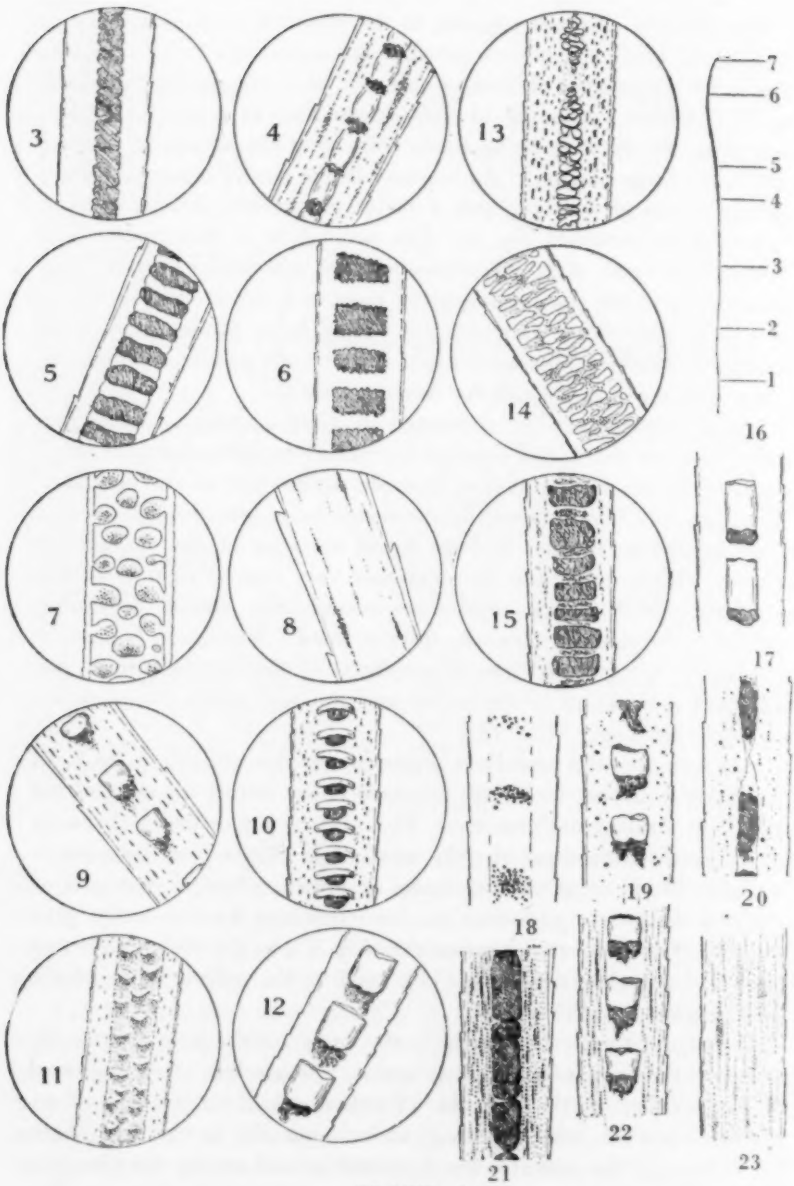

PLATE I

Explanation of Figures 3 to 23

Figs. 3 to 15 represent the conditions in the fur hair of the species, midway from the tip to the base, in each case, unless otherwise noted. For comparison, the diameter of each hair is given in micra.

Fig. 3. Polar bear (Thalarctos maratimus), 52 μ, color white

Fig. 4. Black bear (Ursus americanus), 46 μ., color, dark brown, almost black.

Fig. 5. Blarina (Blarina brevicauda), 38 μ, color, gray.

Fig. 6. Sewellel (Aplodontia californica), 25 μ., color, dark gray.

of the big brown bat (Fig. 8) is a typical example of a pure brown hair which owes its color solely to cortical granules. Fig. 23, from the tip of the fur hair of the muskrat, and Fig. 29, from the tip of the protective hair[3] of the same species, illustrate the same conditions of cortical pigmentation.

In most instances, however, the colors in hair are produced by a combination of cortical and medullary pigmentation, sometimes with the addition of diffuse color as well. In the hair of the black bear (Fig. 4), for example, the color is due to very dark brown cortical granules, plus black medullary masses. Light brownish or yellowish cortical granules, plus dark brown medullary masses, produces dark brown fur, as in the New York weasel (summer pelage), Fig. 9. Fig. 10, taken from near the tip of the fur hair of the large blarina, shows the usual pigmentation conditions in a dark grayish brown hair *i e.*, black medullary masses, and some few light brown cortical granules. Figs. 13 and 15, hair from the squirrel monkey and marmoset, respectively, illustrate the typical conditions found in yellow or yellowish hairs, *i. e.*, yellow granules both in medulla and cortex, or yellow granules in cortex, and yellow masses in the medulla.

These descriptions of pigmentation characters have been adduced thus in detail to show that the significant thing from the standpoint of fur identification is not the structural cause of the different colors, but that pigmentation characters can be used as aids in identification.

The pigmentation in the fur hair of a species often differs from that in the protective hair. There is likewise a change in the character if the pigmentation from the base to the tip of both varieties. The nature of these pigmentation differences in the hairs of the same animal can be well illustrated from the hair of the muskrat. Fig. 16 shows an entire muskrat fur hair, from base to tip. The numbers 1 to 7 refer

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Fig. 7. Sennett Kangaroo Rat (Perodipus sennetti), 40 μ., color, gray.
Fig. 8. Brown Bat (Vespertilio fuscus), 8 μ., color, brown.
Fig. 9. New York Weasel (Putorius noveboracensis), 10 μ., color, brown.
Fig. 10. Blarina (Blarina brevicauda), tip of fur hair, 30 μ., color, grayish brown.
Fig. 11. Prairie dog (Cynomys ludovicianus), 50 μ., color, yellow-brown.
Fig. 12. Cottontail rabbit (Lepus sylvaticus), 10 μ., color, brown.
Fig. 13. Squirrel monkey (Chrysothrix sciurea), 47 μ., hair from wrists, color, deep yellow.
Fig. 14. Guinea pig (Cavia porcellus), 76 μ., color, yellowish.
Fig. 15. Marmoset (Hapale jacchus), median band of yellow in the fur hair, 25 μ., color, yellow.
Fig. 16. Muskrat (Fiber zibethecus) the entire fur hair, to serve as a guide figure. The numbers, 1, 2, 3, etc., refer to points represented by Figs. 17, 18, 19, etc.
Fig. 17. Muskrat-Character of pigmentation at point 1, Fig. 16.
Fig. 18. Muskrat-Character of pigmentation at point 2, Fig. 16.
Fig. 19. Muskrat-Character of pigmentation at point 3, Fig. 16.
Fig. 20. Muskrat-Character of pigmentation at point 4, Fig. 16.
Fig. 21. Muskrat-Character of pigmentation at point 5, Fig. 16.
Fig. 22. Muskrat-Character of pigmentation at point 6, Fig. 16.
Fig. 23. Muskrat-Character of pigmentation at point 7, Fig. 16.

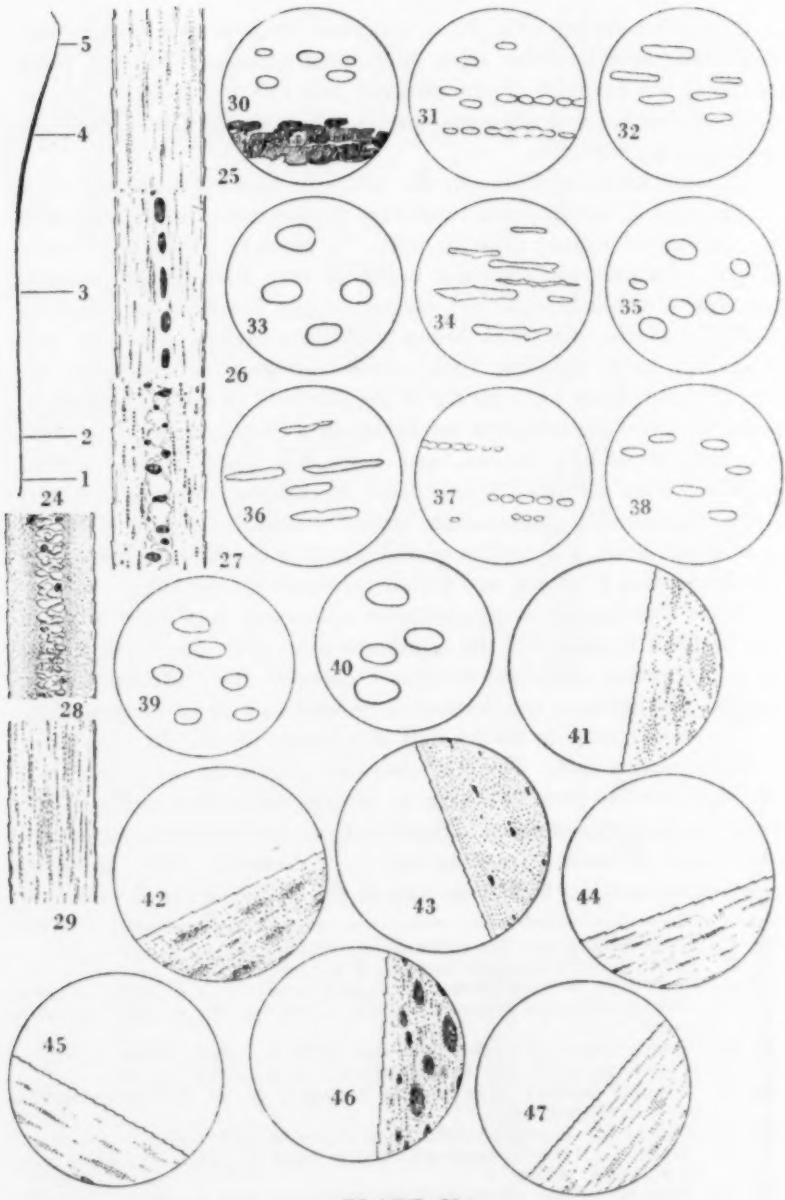

PLATE II

Explanation of Figures 24 to 47.

Fig. 24. Muskrat (Fiber zibethecus), the entire protective hair, to serve as a guide figure. The numbers 1, 2, 3, etc., refer to points represented by Figures 25, 26, 27, etc.

Fig. 25. Muskrat-Character of pigmentation at point 1, Fig. 24.

Fig. 26. Muskrat-Character of pigmentation at point 2, Fig. 24.

Fig. 27. Muskrat-Character of pigmentation at point 3, Fig. 24.

Fig. 28. Muskrat-Character of pigmentation at point 4, Fig. 24.

Fig. 29. Muskrat-Character of pigmentation at point 5, Fig. 24.

to localities illustrated by Figs. 17 to 23, respectively. It will be noted that there is a progressive increase in the density of the pigmentation from base to tip, as well as a change in the nature of the relationships between the black medullary pigment masses (Fig. 17), the brown medullary masses (Fig. 18 to 22), and the brown cortical granules (Figs. 19 to 22). A somewhat similar color change can be followed along the length of the protective hair of the muskrat, (Figs. 24 to 29).

The pigment granules themselves, particularly those present in the cortex, also show variations. These are variations in form, size, color value and color depth, and are susceptible of accurate comparison, as an aid in determining to species-source of the hair, or part of the body from which the hair was taken. As has been pointed out in the case of the muskrat, the character of these granules bears a relationship to their position in the hair shaft.

The value of the prosecution of the detailed study of pigmentation of mammal hairs may be looked for in the application it may have to problems connected with the artificial coloring of furs; in its value for the additional data which it yields for the identification of the species-source of hair samples, and especially in the possibility which

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Fig. 30. Coypu rat (Myocastor coypus), pigment granules, midway from tip to base in fur hair. Length, 0.775 μ.
Fig. 31. Sea Otter (Latax lutris), pigment granules, midway from tip to base in fur hair, Length, 0.46 μ.
Fig. 32. American Otter (Lutra canadensis), pigment granules, midway from tip to base in fur hair. Length, 1.18 μ.
Fig. 33. Muskrat (Fiber zibethecus) pigment granules in tip of fur hair, Length, 0.91 μ.
Fig. 34. Squirrel monkey (Chrysothrix sciurea), pigment granules, midway from tip to base in yellow hair of wrists. Length, 1.80 μ.
Fig. 35. Fur Seal (Callorhinus alascensis), pigment granules near base of protective hair. Length, 0.76 μ.
Fig. 36. Black bear (Ursus americanus), pigment granules midway from tip to base in fur hair. Length, 1.20 to 1.85 μ.
Fig. 37. Brown Bat (Vespertilio fuscus), pigment granules midway from tip to base in fur hair. Length, 0.20 to 0.53 μ.
Fig. 38. Chinese (Manchu), pigment granules in head hair, midway from tip to base. Length, 0.74 μ.
Fig. 39. Eskimo (St. Lawrence Id.), pigment granules in head hair midway from tip to base. Length, 0.91 μ.
Fig. 40. Fingo (Bantu), pigment granules in head hair, midway from tip to base. Length, 1.06 μ.
Fig. 41. Papuan of New Guinea, pigment granule patterns in head hair, midway from tip to base.
Fig. 42. Fingo (Bantu), pigment granule patterns in head hair, midway from tip to base.
Fig. 43. English girl (hair, golden red), pigment granule patterns in head hair, midway from tipe to base.
Fig. 44. English girl (dark brunette), pigment granule patterns in head hair, midway from tip to base.
Fig. 45. Early Egyptian (floruit, 4,000 B. C.), pigment granule patterns in head hair, midway from tipe to base.
Fig. 46. South African Bushman, pigment granule patterns in head hair, midway from tip to base.
Fig. 47. Chinese (Manchu), pigment granule patterns in head hair midway from tip to base.

it affords of identifying minute fragments of hair, when these may be the only ones available in an investigation, as is sometimes the case in legal work.

It was the possibilities of the forensic application of the study of mammal hairs, which has induced the author to make a cursory survey of samples of the head hair of different races of man, to determine whether the pigmentation characters, so marked among the mammals, might not be equally well-defined in human hair. While the results of this tentative survey have not been conclusive, they are most suggestive.

The coloration of human hair appears to be due, in large measure, to either diffuse pigment (as is the case in "red" hair), or to granules in the cortex. The cortical granules are arranged in patterns, of distinctive size and form, for several of the chief races which were examined. Figs. 41 to 47 illustrate various forms of cortical granule patterns from the head hair of members of different races, and Figs. 38 to 40 depict separate pigment granules. The further study of pigmentation in human hair, may bring to light relationships of forensic significance.

For the study of their pigmentation, mammal hairs need to be prepared in the same way as for the study of the medulla, i. e., cleared and mounted in oils of various sorts, or Canada balsam.[4] They should be examined under the highest powers of the microscope, obtainable with oil-immersion objectives of greatest amplification in combination with 18, 20, and 25-power oculars.

An indispensable piece of apparatus for those who wish to make careful identifications is the comparison ocular. This is fitted to two microscopes, and each microscope exhibits half of its field in the comparison ocular, in such a way that two samples of hairs or other fibers, mounted separately on two slides, can be enlarged to equal magnitudes and brought close together for comparison within the same microscopic field. The utility of such a device will be at once apparent. Figure 2 shows a drawing, made from a photomicrograph, of one of the common fur hairs of commerce, and its imitator. The differences in the pigmentation of the two hairs becomes at once apparent when the hairs are thus brought together for comparison. A micrometer scale in the eyepiece aids in making measurements.

The development of micro-analysis has, during the past several years, been very great, and its utility in industrial fields, as well as in pure science, has been firmly established.

[4]For the technique of hair examination, see Hausman, L. A., Structural Characteristics of the Hair of Mammals, footnote 1.

Papers Presented Before the Section of Social and Economic Science of The American Association for the Advancement of Science

SOME PRELIMINARIES OF PEACE[1]

By the Honorable DAVID JAYNE HILL
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A YEAR ago, at St. Louis, we were discussing the merits of the League of Nations as a mechanism for securing the world's peace. It was then pointed out that the Covenant of the League undertakes to accomplish two separate and different purposes—the execution of the Treaty of Versailles and the establishment of permanent peace in the future. It was then made evident not only that these two purposes are disparate, but that the means to be employed for the realization of them must be different.

Before we can discuss intelligently the problem of permanent peace, it is necessary to distinguish between the termination of an actual state of war and the establishment of the conditions of permanent peace in the future.

An actual war is normally terminated by the exercise of superior force; for war is, by its very nature, a contest of opposing forces, each seeking the mastery of its opponent. The war with Germany, for example, could be terminated in no other way than by overpowering the enemy's forces and compelling the vanquished to accept terms of peace imposed by the conqueror. Such terms were embodied in the Treaty of Versailles and accepted by Germany. Whether they are just or unjust is not in this place a question to be considered. The important point to emphasize is that they were *terms imposed by force*, and that the Covenant of the League of Nations was designed as an instrument to carry them into execution. It creates an armed military and political alliance for the enforcement of the Peace of Versailles.

Considered from this point of view, the League of Nations has a legitimate reason for existence; but why neutral nations, or any nations not associated in the war and directly responsible for the particular peace imposed, should be incorporated in the League, is a question that requires an answer. The obvious answer is, that it is intended to maintain the future peace of Europe *by an armed coalition.*

That this is really the purpose of the existing League of Nations

[1]Address of the President and Chairman of the Social and Economic Science Section of the American Association for the Advancement of Science, Chicago, December 28, 1920.

is evident from the pledge contained in Article X to preserve, unconditionally, the territorial integrity and political independence of every Member of the League; and from the provisions of Article XVI, which declares that a state of war with all the Members of the League will arise, *ipso facto*, whenever a Member fails to comply with the obligations of the Covenant. In express terms, therefore, it is a *war* league, not a *peace* league; since peace is to be preserved, not by voluntary agreement to observe certain principles, but by the threat of war. The conclusion is inescapable that the league is a compact for the exercise of economic and military force, to be brought into operation automatically whenever a provision of the treaty is violated.

It would seem superfluous to insist that this attempt to base the peace of the world on an exercise of economic and military force is a preparation for permanent peace. The settlement of a past war on the terms of the victors, whatever they may be, and the prevention of future wars, are clearly undertakings so fundamentally different, and in truth so incompatible, that they are not to be accomplished by the same means or in the same manner. We rightly use force to subdue an enemy who challenges our rights; but we can not base permanent peace upon the pretension of any group of nations that a nation wronged may not defend its rights by force of arms, except by the permission of that group.

And here it is important to note the fact, that there are in Europe, including the United Kingdom, according to the latest statistics, 247,848,168 inhabitants, occupying a territory of 1,410,219 square miles, who are represented by their governments in the League of Nations; and 271,701,401 inhabitants, occupying 2,721,118 square miles, who are not represented in the League of Nations—that is, the non-members in Europe *exceed* the members of the League of Nations in Europe by 23,653,233, occupying territory of *twice* the extent of that occupied by the inhabitants of Europe, including the United Kingdom, represented in the league.

At present, it is true, the league contains the nations possessing the greater military strength; but it does not follow that this will always be the case, especially if there should be dissensions among the members of the league. At most, the league represents only a small preponderance of military efficiency, consisting chiefly in the possession of superior armament, and not at all in numbers. The retention of this preponderance will require the enforcement of the policy of preventing the non-members from arming, while the members continue to maintain their armed forces. But this is, in effect, a continuation of a latent state of war.

It can not, therefore, be said that, even if the terms of the treaties made at Versailles, St. Germain and Sèvres can be enforced, they insure

the permanent peace of Europe. This is not to affirm that the victory of the Allies was not an essential step toward permanent peace. On the contrary, it was absolutely necessary. The lesson it has taught is, that, however formidable an aggressor may appear at the momment of aggression, the world can not be permanently ruled by military force. The appeal to force is in itself a challenge to all that is highest and best in human nature. The resort to military force as a means of maintaining the right to control the action of other nations is in its very nature a menace of despotism, and there never has been, and never will be, any permanent despotism in human history.

Herein lies the fallacy of the whole theory of enforcing peace universally by military power. There never was, and there never can be, any permanent exclusive monopoly in the power to enforce the conditions of peace. The mere pretense of possessing it is a declaration of war. The reason is that this pretension strikes a fatal blow at the whole theory of self-government, for it implies a superiority of right and of judgment in the possessors of power which no nation can rightly claim to possess alone, and which no self-constituted council of nations can vindicate the right to exercise.

When civilization is attacked, it will always find means to defend itself; but civilization can never be more plainly or more fundamentally attacked then when a self-constituted combination of powers assumes the authority to say that a nation shall not vindicate its rights by force of arms when there is no other available means of redress.

What then is the true foundation of peace? It is the provision of means of redress without a resort to arms. It is the recognition of a right to those conditions of life that are essential to the satisfaction of a people's needs, and the establishment of a tribunal before which a nation's wrongs may obtain the judgment of a just judge.

I have spoken of the rights and wrongs of nations, because the existence of organized nations is not only a historic fact but a human necessity. There cannot be a world government that is not supported by national governments; for government, aside from futile dreams of universal empire, is of necessity local in its bases. It is a process of development by which families and communities establish the conditions of life with their neighbors. History is largely made up of the efforts of men to impose upon others submission to their control, but it has never anywhere been permanently successful except by the consent of the governed. The whole foundation of peace must be sought through the recognition of that consent.

The basis of human life is material subsistence. The standard of peaceful living is accepted law. These are the essential prerequisites of permanent peace. Without them it is illusory to try to enforce it anywhere.

What is needed at this time is a reorganization of the Society of Nations *as a whole,* including *all peoples* that maintain a responsible government; and the test of responsible government is acceptance of International Law, which is based on the inherent rights of sovereign States, and obedience to that law. What International Law *is* can only be determined by a properly constituted international tribunal. It should be a tribunal to which all responsible governments may appeal, *of right,* for the redress of their wrongs. What International Law is to *become* will depend upon the willingness of the nations to accept freely and support faithfully the principles of jurisprudence which are held to be governing in civilized states, and these are not difficult to determine.

Can it be claimed that it is the prerogative of any minority league to make the Law of Nations, and to apply it through a tribunal created exclusively by itself? If not, is it not evident that the league can not by its superior force, make itself a substitute for the Society of Nations? Does it not then become clear that the reorganization of the Society of Nations must be accomplished by the cooperation of nations outside of the league with those inside of it?

To this it may be answered, that the Society of Nations could be completed by eventually admitting *all* responsible nations into the league.

This would be so if the league were not a military alliance, and were open to all responsible nations, without other conditions than their voluntary consent to enter it and their free participation in amending it; but the nature of the existing league does not admit of this choice and this freedom. It is a predetermined compact, designed not to meet the necessities of a free association of equals, but to carry out the purposes of the victors in rendering the vanquished powerless now and hereafter. It would be illogical, for example, to admit Germany into this league, which has been organized expressly to impose penalties upon that nation; and admission would never be sought for any other purpose than defeating the object of the league in this respect. And yet, why has not Germany, if able to maintain a responsible government, having accepted the terms of peace imposed, a perfect right to a place in the Society of Nations, and to appeal to a neutral tribunal capable of deciding whether or not she fulfills her treaty obligations? If a nation, though conquered, has not that right does it not continue to be at the complete mercy of its conquerors?

It will perhaps be said, that, until a conquered nation has fully paid all the penalties imposed upon it, there can be no certainty that it possesses a responsible government, and should, therefore, be excluded from the Society of States.

If this position be accepted, what hope is there of ever arriving

at peace? Can peace really be made with a nation whose government is not responsible? Can a nation ever form and maintain a responsible government, unless it entertains the hope that through it peace can be made? Is there any prospect of ever executing a peace, unless it is assumed that it is made with a responsible government? In brief, what motive is there to accept, and attempt to fulfill, the terms of peace imposed, if a nation is to be wholly excluded from the Society of Nations, is not accorded equal rights under the Law of Nations, and has not the right to appeal to a neutral tribunal to determine whether or not it has fulfilled its obligations? If those obligations may be arbitrarily interpreted, and especially if they may, from time to time, be arbitrarily increased, with no opportunity of redress, what becomes of the pretension that peace has been made?

Would not a full conference of responsible states—the standard of responsibility being full acceptance of International Law and actual conformity to it—where the members of the Society of Nations might meet as juristic equals, furnish an occasion for reorganizing that Society in its true sense? Could not the nations, both victors and vanquished, meet there upon the assumption that a formal peace having been made, a friendly disposition might make that peace effective between the peoples that have been at war? Obviously, no such meeting as this could be held under the auspices of the League of Nations, while organized as a military and political alliance.

Would such a meeting of the Society of Nations, confined to specific peaceful purposes, furnish new occasions for collision?

The answer lies in the will of the peoples of Europe. If there is a sincere general desire for peace, a real peace is possible. If there is not such a desire, the League of Nations certainly can not long preserve the peace by force of arms.

We need not enter here into any discussion of American policies. These are now under consideration by responsible and competent authorities, and it is to be hoped that they will be framed in a sense to unite every party and every faction of the American people upon a course that will give us peace and at the same time enable us to fulfill every obligation of national duty. But here, in this gathering of men and women devoted to truth for its own sake, and to the recognition of those facts which form the material of social and economic science, it is not beyond our province to consider, as we have attempted to do, the grounds on which permanent peace may be established. We are not indulging in theory, but are merely interpreting human experience, when we say, that among the necessary preliminaries of lasting peace are the conditions of life which meet the essential needs of men and of nations, and a bar of justice before which the wrongs of nations may be presented for at least that measure of redress which the unselfish opinion of civilized mankind can give.

WAR RISK INSURANCE

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THE stage has been reached when we may carefully consider the failures and accomplishments of the Bureau of War Risk Insurance and thereby arrive in our own minds at a conclusion as to whether or not the legislation creating the Bureau was short of vision, whether or not such legislation was intended for a war emergency only, and when we may discuss the social and economic place of the function and activity of the Bureau of War Risk Insurance as it affects the life of our nation.

Before going into these phases of the question, it may possibly serve to clarify our thought if we consider the history of the legislation bringing forth the Bureau of War Risk Insurance. To begin with, the Congress of the United States felt it should provide something in the way of protection against war hazards. What contingencies, would in the opinion of the War Congress be considered as the main hazards to be provided against? There was—first, the marine hazard of war, second, the economic and social hazards of the dependent relatives of the fighting forces, and third, the physical hazards resulting in complete or partial disability, or terminating fatally with the decedent leaving behind a dependent family.

In providing for these main war hazards there has developed, as of June 30, 1920, what might be regarded as five of the largest businesses of their kind in the world:

1.	Marine insurance (war risk) total amount written	$ 2,390,074,384.82
	Premiums received on above less claims paid representing a profit of	$ 17,500,897.92
2.	Allotments and family allowances paid	$ 554,691,626.25
3.	Compensation for death or disability as a result of service (total expenditure to June 30, 1920)	$ 114,765,422.84
4.	Insurance on military and naval forces (Total volume war risk term insurance written to June 30, 1920)	$40,284,892,500.00
5.	The largest medical practice in the world with the total number of patients admitted to hospitals	54,779
	And patients given treatment and examination	452,609

We will first trace the exigencies of the war period as it called forth the enlarged scope and activity of the bureau.

What can be termed as the original War Risk Insurance Act was passed by Congress on September 2, 1914. Immediately on the outbreak of the European War, Congress, in order that the commerce of the United States might be adequately protected, created in the Treasury Department a bureau charged with the duty of insuring American vessels, their freight and cargoes, against loss or damage from risk of war.

It is to be remembered that the initial legislation did not cover marine insurance, but covered solely war hazards. Such war risk insurance was brought forth by necessity. If the commerce of the world was to be safeguarded, national legislation should be passed. No private insurance company could assume the risk except by charging the almost prohibitive rates, which, because of the peril resulting from modern warfare, it would be called upon to charge.

The original War Risk Insurance Act of September 2, 1914, was further amended to insure the crews of vessels against death or disability resulting from war.

By the legislation creating marine and seamen's insurance, the government embarked upon what proved to be the most stupendous and successful marine insurance business which the world has ever known, and which resulted in stabilizing the commerce of the entire country, as well as causing renewed confidence in the government. The vastness of the business undertaken can be easily grasped when it is known that the total amount of insurance written was $2,390,074,384, and the success with which the bureau administered this function given by Congress, and the united support which the bureau received from our own navy as well as those of allied governments, can be appreciated when it is known that the premiums received, less claims paid, represented a profit of $17,500,897.

With the cessation of active hostilities on November 11, 1918, the activity relating to the marine and seamen's feature of the War Risk Insurance Act was brought practically to a close.

The most widely known functions of the bureau, however, are found in the administration of the War Risk Insurance Act as it relates to soldiers or sailors allotments and government allowances, insurance, and compensation, which were provided for by the Act approved October 6, 1917.

Let us first consider the social and economic reasons that called forth this last classified legislation. Congress had passed the Selective Service Act, believing it to be the best means by which the army of this great democracy should be formed, to the end that the armed forces should be assembled and trained without discrimination to class, caste, or creed. Congress increased the pay of the enlisted man by about 100 per cent. and yet felt that the drafting into military or naval service of a person would not withdraw the legal and moral obligation of each man, wherein the necessity existed, to contribute to the support of his family. The breadwinner had been taken from the home, and it was evident that some method should be devised to alleviate the attendant financial distress that would inevitably follow.

Congress further appreciated that no army, however strong in numbers, could wage a successful warfare if the morale of the country

supporting such army were at a low ebb. By Article II of the War Risk Insurance Act of October 6, 1917, provision is made for the granting of allowances by the government to families and dependents of enlisted men in the military or naval service. The law required the soldier or sailor to allot a certain amount of his pay to certain classes of dependents such as a wife or child, and also to brothers, sisters or grandchildren, he might allot, if he wished, a part of his pay. To this allotment the government would add an allowance to be determined by the number of members in his family and the amount of the man's habitual contribution to their support, previous to entering military or naval service.

Successfully to carry out the terms of this legislation presented a multitude of economic and social problems. The legislation was both liberal and fair, recognizing the legal and moral responsibility of the man to meet the burden which rests upon him in supporting his family and at the same time recognizing his inability while absent from home on military duty to discharge that responsibility.

The government, therefore, agreed to contribute its share, which might amount to a contribution of more than three times the sum which the enlisted man was required to allot for the support of his family. The Bureau of War Risk Insurance was the agency through which this aid was to be rendered. Its doors were formally opened for this purpose on October 6, 1917, with approximately twenty employees.

It was stated at the time of the passage of the legislation that the degree of dependency in the army would approximate forty-five per cent. of the total enlistment. Hence about 900,000 applications for allotment and allowance would be received as soon as the bureau began to function. No force had been recruited to cope with the volume of work; no facilities were available; army and navy contact necessary for obtaining the information upon which to base allotment and allowance had not been established and the clientèle of this great organization was scattered throughout the various military and naval organizations. These were some of the almost insurmountable problems immediately confronting the bureau. I can not infringe upon your time other than to point out some of the difficulties which in the beginning faced the bureau.

The bureau undoubtedly failed in many instances to render prompt aid and thereby relieve many cases of dire distress, but I believe when the accomplishments are measured by the failures, the bureau will receive favorable commendation.

As a result of the administration of the allotment and allowance feature of the War Risk Insurance Act, the bureau became one of the largest financial institutions the world has ever known. Requests for allotment and allowance from October 6, 1917, to the close of this

fiscal year, June 30, 1920, totaled 1,666,607. There were in addition 2,807,093 application blanks returned on which no allotment and allowance was requested. It was necessary, however, to go over all of these forms received, in order that a proper index might be made. The total expenditure to June 30, 1920, totaled $554,691,626.25. Certainly from an economic and social standpoint no one will question the vision of the legislation providing for allotment and allowance, nor the family economic stability that resulted.

Congress felt that, inasmuch as relief had been afforded for the period of war by providing for the dependents left behind, and inasmuch as insurance had been and still is a great factor in the family life of the American people, some provision should be made whereby the men whose insurability in a private company had been destroyed by going into the war, or, if not destroyed, would persist only upon the payment of premiums signally higher than those of peace-time, should not individually suffer this economic loss at the hands of the government; instead, that the government should itself grant insurance to soldiers and sailors at a premium rate which took account only of peace-time risk, leaving the cost of administration to be borne as a part of the cost of war.

Congress, therefore, wrote into the War Risk Insurance Act of October 6, 1917, Article IV concerning insurance, by the terms of which insurance might be applied for by men and women in the military or naval service in amounts ranging from $1,000 to $10,000, payable in the event of death or total and permanent disability, no matter from what cause resultant, and irrespective of whether or not such death or disability was incident to military or naval service. Provision was also made whereby insurance applied for during the war period could be converted into government life insurance along the same lines as insurance policies issued by private insurance companies.

By this legislation the government embarked upon an entirely new enterprise, an enterprise without parallel in the history of mankind, the stupendousness of which can be fully appreciated when it is known that in this connection 4,631,993 applications for insurance were received, which totaled a liability of $40,284,892,500, a sum far in excess of the total amount of insurance in force with all commercial companies in the United States.

There has been a great economic question in the minds of some people since the signing of the armistice as to whether or not the government should continue in the insurance business. Should it seemingly compete with private insurance companies? Would the government in this field of enterprise promote the economic stability of the country or would it bring attendant economic distress? Should all war risk insurance be cancelled and a cash bonus substituted therefor?

These are some of the many questions that have confronted Congress and the people at large.

While the Bureau of War Risk Insurance has labored under tremendous handicaps, I believe that the time which has elapsed since the signing of the armistice has proved the stability and value of government insurance.

The government is now paying insurance, as of December 1, 1920, to 131,824 beneficiaries under war risk term insurance, which represents a total liability of $1,169,597,021.63 to the government. This does not mean, however, that this last named amount of money will be immediately disbursed because war risk term insurance is payable in monthly installments extending over a period of twenty years.

There has been one great difficulty in the administration of the insurance feature of the War Risk Insurance Act and that has been because the work of the bureau is by legislation centralized. Legislation and appropriations do not permit of the bureau's establishing satisfactory contact in the field. Could a large private insurance company hope to maintain a high degree of efficiency were it possible to have only one central office through which all correspondence, the writing of insurance, and the settlement of claims should be handled, and should not the bureau be allowed the opportunity of taking this great economic relief provided by insurance to the homes of all ex-service men and women? If knowledge of this opportunity could be taken to the home of every ex-service man and woman would it not react favorably upon the social and economic life of the nation as a whole? But in spite of this difficulty the approximate data as of December 1, 1920, discloses that 347,664 men and women have continued their war risk insurance amounting to $2,882,736,500.00, and 228,615 men and women have converted their war term insurance into government life insurance, the converted insurance amounting to $775,717,000.

Can you visualize the tremendous and far-reaching economic stability to our nation should there be more than four and one-half million men and women in the prime of life who had fortified themselves and provided for their dependents by carrying insurance in the amount of $10,000?

I must hasten to the last great feature of the War Risk Insurance Act and that is the provision for the payment of compensation. Congress desiring to be free from the pension complications following previous wars provided compensation payments in case of death or disability connected with military service, not merely a gratuity, but compensation based somewhat upon the compensation laws of the different states and computed according to the family status or the degree of disability suffered.

It should be pointed out that compensation benefits are completely distinct from those of insurance. An insurance award has no influence or bearing whatever on a compensation award for the same death or disability, and *vice versa*. Insurance is a government contract with a soldier or sailor, whereas compensation is a government grant which is discontinued upon the termination of the contingency necessitating it. Payments of the benefits of insurance are payable without regard to a line of duty status, while compensation payments are dependent upon a line of duty status.

The bureau had adjudicated, as of December 1, 1920, 437,588 claims for death and disability compensation. The last monthly payment for compensation being paid to disabled soldiers amounts to $10,164,493.09 and the last monthly payment of the bureau to the dependents of deceased soldiers amounted to $1,345,617.42. The total amount disbursed to December 1, 1920 by the bureau for compensation purposes amounting to $163,979,175.25.

In providing for the payment of compensation the bureau can justly be termed the largest employees liability company the world has ever known.

The bureau is also charged with the responsibility of providing medical care and treatment for disabled soldiers and sailors where such disability is traceable to military or naval service, and in this respect, has given medical care and treatment as of the close of the present fiscal year, June 30, 1920, to 452,609 patients with 54,779 having received hospital treatment. There are now in hospitals scattered over the entire United States approximately 23,000 ex-service men and women.

The medical activities of the Bureau of War Risk Insurance throughout the country is a function of the United States Public Health Service acting under the joint authority of the director of the Bureau of War Risk Insurance and the Surgeon General of the United States Public Health Service. In order better to administer the vast number of physical examinations and the hospital relief incident to the proper execution of the War Risk Insurance Act, the Surgeon General of the United States Public Health Service, acting for and in behalf of the Bureau of War Risk Insurance, has divided the continental United States into fourteen districts and detailed a medical officer to take charge of the organization of each such district.

In June, 1920, the Congress of the United States, realizing the imperative need of additional hospital facilities, approved the utilization, where feasible, of government hospital facilities of the United States Army and Navy, and the National Homes for Disabled Volunteer Soldiers. This act on the part of Congress greatly relieved the acute hospital situation. The director of the bureau also entered into

negotiations, with the State of New York, and as a result of such negotiations, that state passed legislation authorizing the construction of a $3,000,000 hospital for the care of disabled soldiers and sailors suffering from mental disorders, such hospital to be leased to the government with the option of purchase at the expiration of a ten-year period. The authority of the government thus to contract with a state is now before Congress.

In discharging the functions required by law of granting marine and seamen's insurance, allotment and allowance, insurance, and compensation, the present director divided the work of the bureau into several major administrative divisions, having an assistant director or chief in charge, who is held responsible for the work of such division. The director through intensive study of the flow of work throughout the various divisions of the bureau has lessened duplication, and by the installation of many labor-saving devices improved the character of the work performed as well as made possible a material reduction in the total personnel of the bureau. At one time the bureau's personnel totaled over 17,000 while now the entire personnel of the bureau numbers 5,775. This reduction has taken place in spite of the fact that the work of the bureau has increased, and still further reductions in personnel are contemplated.

The present director of the bureau has also installed a central record control for the entire bureau in order that he may get daily reports of the work of each particular division, and in order that he may have knowledge at all times of the exact flow of work. A carefully planned budget system has also been put into effect.

There are many legislative relief bills pending. The Wason Bill which has passed the House of Representatives and is now before the Senate for action, provides for the decentralization of the activities of the bureau and for many other advantageous adminstrative steps. There is also before Congress an adequate program for the construction of government hospitals.

The most radically re-constructive bill now before Congress is for the consolidation of all agencies having to do with ex-service men and women and their dependents. Certainly to establish and co-ordinate the work of the United States Public Health Service, the Federal Board for Vocational Education, and the Bureau of War Risk Insurance, by bringing all agencies under one directing head, will be a great step forward in meeting the immediate needs of ex-service men and women and in relieving much duplication of work with relief from that attendant delay that inevitably follows such duplication.

I am thoroughly in accord with this plan to have all of these agencies co-ordinated under a sole directing head.

Early in my administrative effort as director of the Bureau of War

Risk Insurance I became conscious of the fact that while the responsibility of conducting the affairs of the bureau rested upon the director, subject, of course, to the general supervision of the Secretary of the Treasury, that the work of the bureau was no one man's job, that the full counsel and cooperation should be secured of all who were equally interested and concerned in order to make the bureau's work most effective and so that the provisions of the War Risk Insurance Act could serve effectively all those whom Congress intended should be benefited thereby.

The influence and cooperation of you, gentlemen, whose sphere is unlimited, is not only desirable, but is essential to the proper carrying out of the government's program in meeting adequately the needs of ex-service men and women.

PRESENT NEEDS OF THE UNITED STATES PATENT OFFICE

By ROBERT F. WHITEHEAD

COMMISSIONER OF PATENTS

UNDER Article 1 of Section 8 of the Constitution, Congress was granted power to promote the progress of Science and Useful Arts by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries.

Under this power Congress has passed laws authorizing the issuance to any one who has made a new and useful invention in an art, machine, manufacture, or composition of matter, of a patent for a term of seventeen years, granting to the patentee the exclusive right to make, use and sell his invention or discovery.

To the Patent Office, Congress has given the duty of examining all applications for patent and determining whether the applicant is justly entitled to the patent which he seeks.

While many people are more or less familiar with patents, few realize to what extent all classes of citizens are affected by the work of the inventor who is largely stimulated to do his work by the hope of a reward from the granting of a patent.

The Patent Office deals with all the efforts of the world in every field of industry to advance the useful arts. In his report for 1916 the Commissioner of Patents, as illustrating the various interests both public and private which are involved and the extent of such interest, said:

> What great interests are involved, not merely of private but of public concern, may be illustrated by a few examples relating to the field of conservation of fuel.
>
> The Commonwealth Edison Company of Chicago reports that it has

effected a reduction in coal consumption from nearly seven pounds per kilowatt-hour to 2.7 pounds per kilowatt-hour within the last 10 years. With this and other economies the cost to the consumer per kilowatt-hour was reduced in 1915 to one-sixth the cost of 1905, and the company in 1912, with a consumption of 1,103,230 tons of coal, produced an amount of electricity which on the basis of the apparatus of 1902 would have required the consumption of 2,650,000 tons.

The Seventy-fourth Street Station of the Interborough Rapid Transit Company of New York City has recently introduced improvements which, it is reported, have caused a drop of coal consumption from 2½ pounds per kilowatt-hour to 1½ pounds per kilowatt-hour.

It is estimated that the new steam plant of the Buffalo General Electric Company at Tonawanda, N. Y., will generate electricity from coal more cheaply than can be done from the waters of Niagara Falls.

The great economies are due, in large measure, to the modern automatic stoker and regulator, to furnace construction, to forced draft, to coal-handling machinery, and other inventions.

What has gone on in this particular field has been going on in almost all of the fields of industry known in 1890 and in many which have been discovered since that date.

New arts have been discovered such as wireless telegraphy, telephony, and control of torpedoes, searchlights and gun pointing, vacuum cleaning, X-ray apparatus, liquefaction of air to produce oxygen and nitrogen for commercial use, flying machines, the moving picture and mercury-vapor lamps.

Advances have been made, of enormous importance, in chemical methods and materials, such as catalytic materials used in the manufacture of sulphuric acid and ammonia, and in the hydrogenation of organic substances; hydrogenization of oils whereby new products are obtained from cotton-seed oil; the discovery of cellulose esters; almost innumerable coal-tar products useful in pharmacy, dyeing, and photography; gas manufacture, such as acetylene gas; evaporation and drying of milk; gasoline manufacture; fixation of atmospheric nitrogen with resultant production of synthetic ammonia and nitric acid; rapid vulcanizing; glass making; manufacture of synthetic resins; recovery of potash from silicates for the manufacture of fertilizers.

By way of illustration, I will cite certain facts relating to bread making reported to me by the Mellon Institute. For a period of some five years an industrial fellowship has been maintained there, in which trained scientists have devoted their time to the study of methods of bread making, with the object of producing better bread. Certain of the processes developed have been patented and put into operation on a large scale and it is found that they not only produce better bread, but effect great economies. Better nourishment of the yeast has reduced the amount required in raising the bread and maturing the dough, with consequent lessening of the amount of flour and sugar which is used up by the yeast and converted into carbon dioxide and alcohol. The saving of these and other economies to those employing the novel processes are estimated to amount to over $1,000,000 per annum. This estimate is based upon the present high scale of prices, but on any scale of prices would be enormous.

The economy is illustrated in another way, as follows: The average flour production for the State of Kansas is about 20,000,000 barrels, or roughly, 4,000,000,000 pounds. The saving of flour effected is about 2 per cent., which would amount to 80,000,000 pounds, or 400,000 barrels annually on the production of this one State.

In the field of electrical engineering there has come the electric heater, the electric elevator, the supplanting of cable street railways by electric street railways, the electrification of long steam railway lines, train control, storage-battery developments, polyphase and high voltage systems of electric transmission, electro-dynamic phase transformers, long-distance transmission in telephones, and the development of the automatic switchboard.

I personally know of two patents, in the electrical field, both about to expire, each of which shortly after it was granted was sold for a large sum. Neither has been the subject of litigation, yet neither could at any time since the purchase have been bought for many times the sum paid for it.

In the field of farming implements there have come the tractor engines, apparatus for digging irrigation and drainage canals, beet harvesters, corn and cotton planters, deep-soil disk plows, cleaning and manipulation of cotton and wool fiber and other great advances.

But what is true of these arts is true of innumerable others, such as spinning, weaving, manufacture of steel, reinforced concrete for bridges and the like, the steel frame building, stone-working machinery, coal-mining machinery, and oil-drilling machinery.

The automobile has been almost wholly developed since 1890, and there have been vast advances in the construction of internal combustion engines; water purification methods and filters; fire extinguishers; match making, basket and barrel making machines; electrical welding; calcium carbide making; sound reproducing machines; flotation processes of concentrating ores; flour making and refining; shoemaking machinery.

In fact, the list might be extended almost indefinitely; and the prospect is that as great, or greater, advances and discoveries will be made in the immediate future.

Prior to 1836 the system both in this country and abroad was to grant patents on application therefor without any search to determine whether the alleged invention was really new. The system of granting patents on examination, which was established in 1836, was primarily in order to safeguard the public interest by the avoidance of unwarrantable grants.

It is obvious that the more thorough the examination and the more accurate the determination of the scope of a given invention, the more valuable the patent is to the patentee and the less likelihood there is of the improper grant of a patent or the grant of one with claims which are too broad. It is also obvious that in order that such an examination may be made it is necessary that the examining corps be composed of men qualified for such work both by education and experience and that they shall have time not only to examine applications but to study and keep abreast of what is being done in their several arts.

It takes time for an examiner to learn his art and how to handle it efficiently. An excessive loss of trained men is very uneconomical as new men can not for a long time efficiently do the work of those whom they replace.

The salaries paid at the present time to the members of the examining corps are not such as to hold the men or to attract properly trained men to stand the entrance examinations. During the year 1919 there were seventy-seven resignations from the examining corps of slightly over four hundred, and during the first ten months of 1920 there were seventy-eight resignations. The Civil Service Commission has not been able for a long time to furnish sufficient eligibles to fill these vacancies and many of the Fourth Assistant Examiners positions have been filled by making appointments of persons who had not passed the required test.

The greatest need of the Patent Office at the present time is, therefore, such a reorganization of the salaries as will attract graduates of the technical schools and justify them in making this work their life work. In other words, to change the Patent Office from what it largely is at the present time, a mere training school, to an institution offering a real career to its employees.

A bill (H. R. 11,984) for this purpose was passed by the House of Representatives last year and is now in conference, having been passed by the Senate in a somewhat different form. If this bill becomes a law it is believed that the desired results will largely be obtained.

If the examining corps could be stabilized not only would examinations for ascertaining the novelty of inventions be better made but the work could be kept much more nearly up to date. At the present time, due to the overturn in the examining corps and to a very large increase in the number of applications being filed, the work is far in arrears. In many instances this delay works a hardship on inventors and their assignees.

Another need of the Patent Office is the completion of the work of reclassification of existing patents. This work was begun some twenty years ago, but from time to time has been slowed down owing to the inability of the force to keep up with the examining work and also carry on reclassification work. At the present time it is not being pushed as vigorously as it should be for the same reason. With the increased force provided for by the pending bill above referred to this work can be proceeded with more rapidly. When all the patents have been classified the question can then be taken up of the desirability of publishing briefs of the inventions and abridgments such as published by the British Patent Office.

The Patent Office needs now more room and that need is becoming greater each year Not only are some of the examining divisions overcrowded and many of the clerks working under undesirable conditions, but there is not room available for the needed expansion of the public search room, the Scientific Library, and the storage of the rapidly accumulating records. This relief will have to come either by the erection of a new building or by allowing the Patent Office to occupy a portion of the building across F Street, which is connected to the Patent Office by a tunnel. Plans had been worked out for transferring certain divisions of the Patent Office to this building but at the outbreak of the war it was found necessary to assign this space to the War Department and the plans could not be carried out.

The work of the Patent Office has increased immensely in the last two years. While statistics are not usually very interesting it may be well to point out how great the increase in the work has been.

During the year ending June 30, 1919, there were filed 62,755 applications for patents for inventions, while in the year ending June 30, 1920, there were filed 81,948. The total number of applications, including applications for the registration of trade-marks, prints and labels, filed in the former year was 75,657 and in the latter 102,940. The increase in the applications for patent was 30% and in the applications for the registration of trade-marks 72%.

INTERNATIONAL ECONOMIC IMPORTANCE OF PRECIOUS STONES IN TIMES OF WAR AND REVOLUTION

By Dr. GEORGE F. KUNZ

PRESIDENT, AMERICAN SCENIC AND HISTORIC PRESERVATION SOCIETY

ALMOST from time immemorial gold and silver have been acknowledged as the standard precious metals. For twenty-five centuries they have been used in coinage, varying from gold at eight times to forty-five times the value of silver and now receding to about fifteen times. Up to the present time seventeen billion dollars worth of gold has been mined, of which five billion has been lost, leaving twelve in circulation and in the arts. There are now in the governmental treasuries or in banks approximately nine billion dollars worth. Frequently treasures of gold are found in earthen or leaden pots, dating from five centuries before Christ to the Christian Era, which are absolutely perfect and as intact as the moment they arrived from the mint.

Although at various times in various parts of the world corn, rice, rock salt, cocoanuts, dates, shells, whale's teeth and wampun have been used as a medium of exchange, they only had a local value and were not international. The paper moneys of the world have little durability, and there is scarcely a paper note known that has held its value for more than a century. Even our own Colonial bills, and bills of the Confederate States have no value other than to an antiquarian. Of all known metals, nothing possesses the compactness in value, the rarity, the richness and the convertability in every capital of the world, of precious stones, whereas 100 ounces of gold would be as much as any individual could comfortably carry about with him, approximately $2,000 worth.

Precious stones in all times have been prized as the only objects that can be transported in great value with the least possible bulk. Many precious stones have such value that a million dollars worth do not weigh more than a few ounces to a few pounds, and in the great World War and the aftermath of the War, in Russia and other European countries, these were hurriedly bought and there are many instances on record in which they were the only objects that it was possible for the owner to flee with, sometimes at only half an hour's notice, and, as they have no international mark, as would a coin or a banknote, they could be converted in any country to which a refugee departed.

In regard to paper monies, with the exception of the money of the United States, all other issues have depreciated over 10 per cent., or, in some instances, as in Austria and Russia, have fallen to only 1 per

cent. of the original value; and as precious stones exist to the value of $3,000,000,000, this is a large enough value to have an economic importance in times of war and stress. As to permanency of value, the Regent Diamond, sold to France in the time of Louis XV, today, after changes from kingdom to republic, consulate and empire, and again to republic, is itself unchanged and as precious as the day it was bought in its rough state by Thomas Pitt, in the early eighteenth century. Bonaparte pledged it to the Dutch Government to procure funds indispensable to the consolidation of his power. History tells us how the great diamond of Charles the Bold was placed as a loan with the Fuggers of Augsburg, the great money lenders of the fifteenth and sixteenth centuries, or by the inhabitants of India before money could be placed at interest, as forming the only absolutely transferrable international medium of exchange.

About 6,000,000 ounces of platinum have been found, worth about $80 per ounce, approximately $500,000,000, of which two-thirds has been used by dentists and chemists. Therefore it would not be a factor in world values; and is not so easily understood or recognized as is gold or silver.

Preciousness consists of indestructibility, rarity, portability and convertibility. Thus, gold is one of the most important of the precious metals. Alexander the Great, in his time realized that by transporting gold to India, instead of silver, his camels carried thirteen times as much in value. At that time the ratio was about thirteen to one.

The Sultana of Sulu owned a necklace of beautiful pearls. When visitors tried to buy them, she said "Why should I sell them?" They said, "We will give you money for them." She said, "What can I do with the money? If the enemy comes, it is too heavy to flee with. My pearls I could take with me, and if I need money I can always sell a pearl." The Sultana realized the portability and value of pearls.

THE RELATION OF ANTHROPOLOGY TO AMERICANIZATION

By Dr. ALBERT ERNEST JENKS

PROFESSOR OF ANTHROPOLOGY, DIRECTOR OF THE AMERICANIZATION TRAINING COURSE, UNIVERSITY OF MINNESOTA

AS an anthropologist I have long been interested in the practical application of the science of anthropology to the problems of modern American life. I can not better give you my view of the importance of this application of anthropology to modern problems than by quoting from my report to the Carnegie Institution of Washington in 1914, where under the section entitled "Modern Problems" and the sub-titles of "Ethnic Heredity," "Influence of Environment on Man-

kind," "Human Amalgamation," and "An Anthropological Laboratory," I discussed this question at some length. I here quote from the opening paragraphs of that section of the report:

"It must not be supposed that the anthropologist is limited in his interest and his field of work to man's evolution of the past. He knows man is still in the making. He studies man's present-day evolution in its individual and ethnic aspects. He makes his studies of both the past and the present, with an eye to the future, in order that those things which vitiated or benefited the evolutionary process in the past, and which vitiate or benefit it today, may serve as guides for future generations.

"The field of anthropological study of modern people is new and unoccupied, only the barest beginnings having been made. The horizon of this coming field for research among present and future man and ethnic groups is seen to extend indefinitely into the future. It would be difficult to overestimate the practical value of these continued studies. Their utility would be world-wide."[1]

But, however much individual scientists were interested in modern anthropological problems up to the year 1914, our nation as a whole seemed to be chiefly interested in those sciences which could add commercial value to commodities sold in the market. Experts were constantly at work importing to the United States, and distributing here with most careful study, plants and animals which have added millions of dollars to the wealth of the nation. In the meantime there were coming to our shores with very little restriction peoples of many different breeds and cultures who distributed themselves over the United States quite largely as chance or as profit for the moment dictated. Ferrero, the Italian historian, says in his *Ancient Rome and Modern America*: "My first surprise (on coming to the United States), and a very great one it was, arose from my examination at close quarters, of the policy pursued by the United States in dealing with the immense hordes of immigrants, who yearly pour into their harbors from all parts of the Old World." This question was of especial interest, as he said, "to a historian of Rome, like myself, to whom history has taught the great internal difficulties which were caused in every ancient state by the *metoipoi* or *peregrini* [i. e., aliens]."[2]

It was not until America was rudely awakened by a time of national peril that she realized the magnitude of the task before her of assimilating the various peoples in her midst. This problem of the assimilation of our immigrant peoples then became of such importance that it attracted nation-wide attention, and started a nation-wide move-

[1]Reports upon the Present Condition and Future Needs of the Science of Anthropology presented by W. H. R. Rivers, A. E. Jenks and S. G. Morley, at the request of the Carnegie Institution of Washington, printed 1914.

ment known as "Americanization." It is in this field of national endeavor that anthropology has an opportunity for paramount practical service to our nation.

The great problem of the assimilation of the immigrant in America is at base anthropological. Ethnic groups differ one from another. It is commonly supposed to be true that their differences are only "skin deep," but biologists know that ethnic groups differ beneath the skin. They know that the processes of pigment metabolism are so unerring and persistent that patches of skin taken from one person and grafted on another take on the proportion of pigmentation natural to the "stock" or seat on which the transplanted skin lives. They know also that ethnic differences are so much more than only "skin deep" that ovaries transplanted from one person to another person would reproduce children of their own kind without influence by the person who served as "stock" or seat for the transplanted ovaries. There are no experiments of this sort known to me, but what has been proved true with other animals would without question be true of human animals. Thus there is scientific reason to speak of different "breeds" of people whose differing physical characteristics are today due to the factors of heredity resident in the reproductive germ cells. Ethnic differences are not simply "skin deep." They are germinal. They begin at the functional innermost center of the person, and they continue through to the outside. The man who runs sees the outside differences between breeds of people. The anthropologist knows they begin inside in the seeds of the breeds.

Out of the physical man grows the psychic man. As out of these different physical characteristics of the different breeds of people come the psychic characteristics of those breeds of people, it should be expected that the reactions of the different breeds of people would exhibit differences. The practical handler of peoples knows such is the case—whether he is an administrator of colonies, a policeman in any cosmopolitan city, or boss of a gang of mixed "foreigners" on any American railway job. At the present moment it can not be said that these differing reactions of the different breeds of men are due to physical differences or to psychic differences or to social and cultural differences, or to something yet unnamed. All that is known is that different breeds of people commonly possess distinguishing reactions in many of the affairs of life.

The American assimilation problem centers in the various breeds of people who are in our midst. What facts and tendencies of strength and weakness for the future of America are in those various ethnic groups? Some peoples can, do and will continue to build into the

[2]Guglielmo Ferrero, *Ancient Rome and Modern America*, 1914, pp. 139-140.

American plan of development. Others do not, and should not be expected so to develop without due education and often tedious application. Others probably never would. What are the varying reactions of these different peoples in our assimilation process? These are questions for the most careful study, the accumulation of accurate data, and for effort at scientific conclusions and application of conclusions in order that an intelligent public opinion based on known facts, instead of sentiment or prejudice or commercial profits for the few, may dictate our policies and practices in regard to the peoples here.

In discussing this point further I wish to bring you not a theory of what might be done, but to tell you what is being done in the University of Minnesota in the practical application of anthropological knowledge to the problem of immigrant assimilation or "Americanization."

For fourteen years we have been developing anthropological courses in our university. Those courses have consisted not only of the usual foundation courses on the development of man, races and culture, but of courses dealing with modern anthropological problems, especially those of vital importance to our immigrant nation. They have dealt with the peoples who have come and who are coming to America as immigrants, with the dominant characteristics of the diverse foreign peoples now in the United States, their modification in America, and the importance of these peoples to the American nation. We have had courses on the American Negro, taking up the negro in Africa, the development of the negro in America, his present characteristics, conditions, developing tendencies and probable future. We have considered the facts and forces of amalgamation and assimilation in America and those psychic results so essentially American that we call them "Americanisms." We have had courses and seminars of method and research in some of the special ethnic problems of America.

Two years ago the regents of the university established an Americanization Training Course to help meet the national assimilation problem. Its object is the training of Americanization leaders to hasten the assimilation of the various peoples in America toward the highest common standards and ideals of America practicable for each generation. The course is founded on our anthropology courses which had already been developed. These courses were emphasized and strengthened. On top of them, we developed professional courses on the technique, the method and the organization of Americanization work; also courses on the principles of adult elementary education, covering language-study as a fundamental tool in assimilation of peoples, ethnic peculiarities of the language-habit, racial bases for development of educational subject matter, problems of the adult

language-habit substitution, and voluntary *versus* compulsory nationalization of language. We also added such practical field courses as supervised work with foreign peoples in homes, residence communities, industrial plants, public schools, etc. There have been difficulties, since we were so largely in an untried field. Some of the courses of necessity were at first only experimental. Instructors had not always all the training we might have wished. But the contact with workers in the same field, especially as we have been able to bring them in during our summer sessions, when they have come as instructors and students from New York, California, and centers in our middle states, has given a splendid impetus to the development of the work today. The practical value of modern anthropological knowledge can no longer be questioned by one who knows the practical work done by those who have gone out from the training course. We have sent our trained Americanization leaders into several different states and into many different positions, such as those of state directors, city directors, school directors, directors with Y. M. C. A. and Y. W. C. A., churches, women's clubs, and as teachers in schools, homes, communities and industries.

We have sent into South Dakota a state director of Americanization, two regional state directors and two city directors. Professor M. M. Guhin, the state director, writes "Our work in this state is nothing more or less than demonstration work of the Americanization Training Course of the University of Minnesota." President H. W. Foght, of the Northern Normal and Industrial School of Aberdeen, writes, "Mr. Guhin is doing a great work for the State, and Americanization training will go forward as a permanent and distinct phase of education in this State."

Three of our trained leaders have gone to the iron-mining region of northern Minnesota. I quote from a letter of one of them to illustrate the practical use of Americanization training:

> I have had every opportunity to put into practice the work I received at the university. The superintendent of schools, for whom I work, had no idea of the methods used in Americanization work. He merely knew the results he wished accomplished. I was sent out to a mining location, and told to "Americanize" it. Had it not been for the practical courses which I had taken at the university as to the different methods of approach to different nationalities, ways of making oneself welcome in the foreign homes, methods of organization of classes and holding the attention of adult pupils, phonic drills for each nationality, and many other helpful suggestions which I use daily, I should have been entirely at sea in my new position. My experience with the foreign people themselves, which was a part of the Americanization Training Course, has been of especially practical value.

The Superintendent of Schools by whom two of these workers are employed has written for two others to begin at once, and requests three additional workers to begin next autumn.

Our leaders are making good in this practical effort to hasten assimilation in America, not only because they are trained in the professional, technical and practical courses, but, more especially, because

through their anthropological courses, they are equipped to know the different necessary approaches to, and reactions of, the different breeds of peoples among whom they work. Their work is among peoples. They have been trained to know peoples. This Training Course is not yet fully manned or as complete as is desired, due to the almost universal shortage of funds in higher education. We need especially research men in physical anthropology, amalgamation, and environmental influence, as well as experts in certain practical fields. There should be research equipment to investigate many phases of the peoples in America. In fact, there should develop a genuine laboratory of research and of practical application of anthropological knowledge to American problems. The time is coming quickly when this will be developed somewhere.

Not only is this work being done in the University of Minnesota, but under the impetus of the Americanization movement many colleges and universities which had never before had anthropology courses of any nature have recently been putting in courses on modern peoples, especially our immigrant peoples, and some have added various professional courses on technique and method of adult education. Not only are these anthropology courses of value in purely Americanization work, but it will come to be recognized more and more that all economic, social and political problems in America today are intimately bound up with the reactions of the different peoples in our midst. More and more it will be seen that with America's vast heterogeneous population her public school educators, her social workers, her police and correction agencies will have to make practical use of anthropological knowledge of the various peoples with whom they deal.

This paper aims simply to focus attention on one phase of practical anthropological knowledge, namely, as applied to Americanization. In pragmatic America all sciences must be able to prove their practical worth in helping solve our momentous national problem, and it seems to me our experiment proves that modern anthropology is capable of practical service to our nation.

THE NEW WILD LIFE PRESERVE NEAR McLEAN, N. Y.

By Professor JAMES G. NEEDHAM
CORNELL UNIVERSITY

IN the early days of Cornell University, the good field naturalists who first came upon her staff began the exploration of their environment. The lake, the hills, the gorges and the upland reaches of the streams were all examined with a view to discovering what they contained of scientific interest and of educational value. Among the many interesting spots discovered were the bogs near McLean. These cold upland bogs with their strongly marked Canadian fauna and flora early attracted attention. These miniature wastes of water and moss, like those of the far north, lying upon the border of an agricultural region, and easily accessible from the university by a 15-mile ride by rail or motor, have continued to be one of the chief centers of biological interest in the university's rich environment.

After fifty years of visitation by naturalists and collectors and by university classes in many biological subjects, after all the generations of Cornell students have tramped the bogs, probed their beds for peat and marl, tested the springiness of the hanging border of Mud Pond

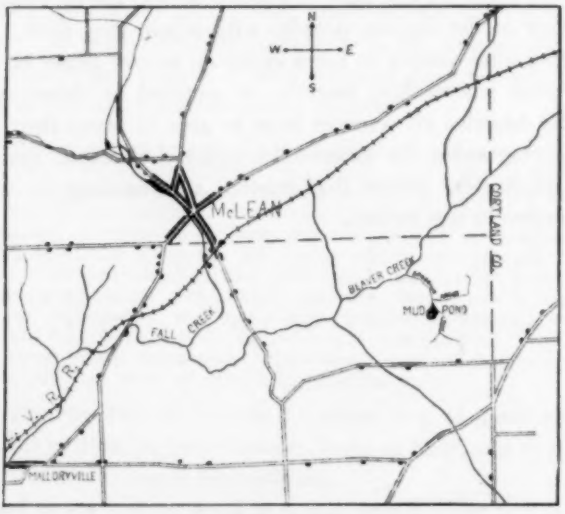

FIG. 1. MAP OF THE ENVIRONS OF THE McLEAN WILD LIFE PRESERVE. MUD POND IS WITHIN IT (SEE FIG. 2). THE CORTLAND-DRYDEN STATE HIGHWAY IS THE ONE PARALLELING ITS SOUTHERN BOUNDARY

with their weight, searched out the rare plants and animals, feasted on the wild berries, drunk from the roily springs, watched for the elusive trout in the dark waters of the meandering streams, and returned home wet and tired and heavy-laden and happy, it has come to pass that this fine bit of wild nature, instead of being "improved" and thus destroyed for the purposes of the naturalists, as have so many others, has been made a wild life preserve. Mr C. G. Lloyd of Cincinnati, himself a mycologist and an excellent field naturalist, has purchased the tract, and has given it into the keeping of the Trustees of the Lloyd Library, in order that it may be maintained in its natural state in perpetuity. An agreement has been made with the trustees of Cornell University whereby the president of the university appoints a professor from one of the biological departments to be custodian of the preserve. President Schurman designated the writer to be its first custodian.

This preserve is easily accessible from railroad station or state highway (Fig. 1), is compact, so that one may see much without traveling great distances. A survey of it was begun in the spring of 1916, by several graduate students in the Department of Entomology and Limnology in Cornell University, three of whom, J. T. Lloyd, P. W. Claassen, and R. N. Chapman, spent the Saturdays of that season in mapping with a plane table, and in collecting from the bogs. Professor A. A. Allen and Dr. C. P. Alexander also assisted in the beginning. American participation in the great world war put a stop to the work and prevented carrying out the survey plans; in the summer of 1916, Mr. Lloyd was in France and the others were scattered about in America, or devoted to more urgent tasks. Only occasional visits to take up the tag ends of the mapping, have been possible since 1916. The results thus far attained have been put together by Dr. Claassen in the accompanying map (Fig. 2).

The McLean Wild Life Preserve lies 15 miles northeast of Ithaca and one mile east of the village of McLean in the valley of Fall Creek at an elevation above the sea level of something more than 1100 feet. It lies in the lowland adjacent to an eastern tributary of Fall Creek known as Beaver Creek or Beaver Brook, and at the foot of slopes that are devoted to fields and pastures, in a region of morainal deposits of great irregularity. It is an uncultivated area of perhaps 100 acres. The basin is an irregular depression in the lowland at the foot of the slopes. It is rimmed about on the north and separated from Beaver Creek by two confluent esker-like ridges that run down from the hills like arms to inclose it. These ridges meet at the point where Sphaerium Brook has cut its way through to join Beaver Creek. The northern arm is the longer, and closely parallels Beaver Creek for the greater part of its length. Its surface is very irregular, as the contour lines on the accompanying map clearly show. Midway its length it rises steeply

FIG. 2.—MAP OF THE MUD POND BASIN, INCLUDED WITHIN THE PRESERVE. THE WET AREAS ARE CAREFULLY SURVEYED; THE CONTOURS OF THE RIDGES ARE SKETCHED. MAP BY DR. P. W. CLAASSEN

from the bank of the creek to a height of 70 feet above the general level in a hump that is locally known as "Observation Hill." On its surface are a number of glacial potholes or sinks. One of them on the northern slope of Observation Hill is usually dry, its bottom being some ten feet above the level of the water in the Creek. Two others on the opposite side of the hill have a much greater depth,, their bottom being some 30 feet below the level of the surface of the creek. These two basins are occupied by the round bogs marked A and B on the accompanying map. There were probably other similar potholes along the inner margin of this ridge, as indicated by the remnants of bog cover at the point marked C and elsewhere on the map. Bog C, especially, has still a somewhat circular outline with zonal arrangement of vegetation about its borders, and a depth of peat in the center of 25 feet.

The southern end of the longer encircling ridge declines to an elevation of about 10 feet at the southernmost round bog (A), and then rises again sharply in a short recurrent ridge some 35 feet high, that projects hook-like into the basin, dividing it into two areas that are very different in character. Northward of this hook lie all the round bogs, covered with sphagnum and heath formation; southward of the hook lie only grass bogs from which heaths are conspicuously absent.

This difference is probably due to differences in the character of the water supply. The round bogs receive only the drainage from the short forested slopes immediately surrounding them. This is soft water—practically rain water. Into the grass bogs, on the other hand, there is poured the drainage from long reaches of tilled fields, together with the outflow from numerous hardwater springs, that feed the brooks, inflowing from the eastward and southward. This is hard water. These differences are clearly indicated by a few sample determinations made by Professor E. M. Chamot of "temporary hardness" expressed in parts per million calcium carbonate.

North side of hook	Bog A	16
	Bog B	16
South side of hook	Mason's Spring	160
	East "	160
	Mud Pond at Outlet	168
At confluence, upper end of Argus Brook in bush swamp		36

Striking as is the difference in surface vegetation of these two areas, the difference in deposits below the surface is still more striking. It is also more significant. By probing the depths of any of the round bogs one finds their basins filled entirely with peat. There is 35 feet of it at the center of Bogs A and B, and 25 feet of it in Bog C. Similar probing in the depths of the grass bogs reveals a surface layer of peat that is underlaid by a deep deposit of marl. At the edge of Mud Pond there is some 11 feet of peat overlying 24 feet of marl.

Probably when the glacier finally retreated from this region to the northward, leaving morainal deposits encircling the basin substantially as they yet remain, the entire basin was filled with water, and the shores of the primeval Mud Pond were approximately coincident with the innermost contours of our map. It had then more than fifty times its present area of open water. It was irregular in outline, somewhat narrowed in the middle portion, curving to northward beyond this, with a westwardly directed bay that was confluent with the pothole now occupied by round Bog B. Detached but adjacent to this was a small round open pond in the pothole now occupied by Bog A.

Then the filling began, and also the cutting down of the outflow channel by Sphaerium Brook. Both processes may have gone on rather rapidly by erosion for a little while, until the soil was firmly held by a complete ground-cover of vegetation. That there has been no very extensive cutting down of the outlet is indicated by three facts: the gradient is slight, the catchment area is small and the flow always limited, and the channel is bedded with cobble stones for the most part, too heavy for so slight a stream to move.

The filling of the pond has been mainly the work of aquatic plants. Those growing about the shore line and on the bottom have contributed their remains in the form of peat and marl, pushing ever farther and farther into open water and adding ever to the deposits, until all that remains open at the present day is a shallow basin 100 feet across. This is the present Mud Pond; and it is filling so rapidly that at the present rate it will be soon, perhaps in less than another half century, entirely overgrown.

Outside the Mud Pond basin, our map shows another grass bog lying in the angle between Sphaerium Brook and Beaver Creek. Though superficially similar to the other grass bogs this one is different in origin. This one was formed originally behind a beaver dam that crossed Beaver Creek some distance below its confluence with Sphaerium Brook. It appears to be maintained at the present time as the upbuilding process goes on, by flood time accretions of silts, deposited along the bank of Beaver Creek. It is everywhere shallow, its depth where samplings have been made not being greater than 8 or 9 feet. It is composed of impure peat, in which from top to bottom there is a goodly mixture of woody stems, of the average size of alder stems. Apparently this bog has been little changed throughout its history. It was formed upon the level flood plain of the creek by damming, the work being done at first by beavers, and later by the natural leveeing of the creek with increase of soil wash from surrounding farms.

The bottom of Mud Pond basin as a whole remains as yet unexplored. Random probings with a marl-sampler have been made in

all the bogs and a few lines of soundings have been run across the grass bogs adjacent to the present pond. These seem to show in the buried contours a row of roundish potholes on the north and a single much larger and somewhat deeper basin on the south. These are connected by a shallower, valley-like depression lying between. These are the two major divisions of the basin, as already indicated, differing in the nature of their catchment areas and water supply; differing strikingly in their plant and animal life, and in the consequent bottom deposits.

The round bogs were once doubtless open circular ponds. They are now completely overgrown. Bogs A, B and C are very similar, though the filling of C is a little more advanced. Each has a central area of dense low-growing sphagnum and heath, surrounded by two zones of larger woody plants. First is a narrow zone of shrubs, and second a wide zone of water loving trees—yellow birch, red maple, black ash, etc.—extending to the foot of the slope. The latter zone is now a cut-over area, studded with stumps of trees only, among which the shrubbery of the first zone, tall ferns and other shade plants, brambles and other immigrants are all struggling lustily for place and standing room. A few scattering worthless trees remain, having escaped the axe.

The more shoal areas of the remainder of the basin, and all the principal areas of silt deposition, whether originally shallow or not, are covered with bush swamp, the dominant species in which is the speckled alder. This alder grows luxuriantly along the silt-strewn edges of all the brooks and about the borders of Mud Pond. Under its shadow in the wetter places grow acres of marsh marigold and skunk cabbage interspersed with swamp saxifrage, and in the plashy edges of the interrupted streamlets, the spreading Chrysosplenium. The alder grows in spreading clumps of usually 4 to 8 strong stems, which gather fallen twigs and leafage about their bases, and thus build up miniature islets in the swamp. On the summit of these such plants as meadowrue and marsh fern and bedstraw and red raspberry find lodgment. The older outer stems of the alder clumps, being loosely anchored in the mud, are borne down to the ground by the heavy ice-coats of winter, and new shoots from the center of the clump arise in their stead. Thus the holding unit is maintained. The alder is the most important plant in the later stages of land building in the basin.

The grass bogs are far less uniform in the character of their vegetation than are the round bogs. Their meadow-like appearance is due to the dominance in them of several species of tussock forming grasses and sedges. These species are of local and irregular distribution, and rarely occur in anything like a pure stand. Where the tussocks are highest—often knee height or higher, so that walking among them is

no easy matter—their height is increased by at least two animal agencies; the ants of the marsh build their nests in the top of the tussocks, and in so doing heap up much material on their summits; the meadow mice excavate runways in the bottom of the narrow channel between the tussocks and eat new shoots springing from severed stems, and thus they deepen the narrow lanes between the tussocks.

The grass bogs lack the heaths of the round bogs, but they contain areas having a considerable admixture of sphagnum with here and there an overgrowth of cranberries. There are marsh ferns also in plenty; and in a wet spot in the largest one, a bit of cattail has obtained a foothold. The edges of all the grass bogs are being invaded by alder.

The filling of the basin is well nigh completed. The work of the plants has been supplemented and accelerated in recent times by human interference. Only one small and shallow pond remains open water and that is rapidly filling up with silt. The grass bogs are merely the openings in the herbaceous bog-cover that are not yet overgrown by alder or other shrub. The largest of these are the two that lie in the southern part of the basin. They are situated on either side of the pond but separated from it and from each other by the shore-bordering alders. A line of probings through the surface peat extending across the middle of the largest grass bogs from north to south at 50 feet intervals gave depths as follows: 5-15-17-19-18-17-18-17-17-3 feet of peat. The depth of the underlying marl was not determined. A single probing of the bed of the larger grass bog in the bush swamp above the surface of Argus Brook at its northeast corner revealed a depth of 18 feet of surface peat. It is altogether probable that a systematic sampling of the deposits of the whole of the whole basin, with careful examination and comparison of the samples, would reveal much of the actual history of the filling process.

The Preserve is being inclosed with a high fence, that will keep browsing farm animals outside. Stiles will be built over the fence at convenient points of access, and one principal encircling path through the woods about the borders of the basin will be kept open. Signs inviting naturalists to enter for study, but not for destruction, will be placed beside the stiles and another guide sign to motorists will be placed at the north side of the state road that runs between Cortland and Dryden a quarter of a mile to the southward. This Preserve is open to all naturalists and all are welcome to visit it.

HISTORY OF BIOLOGY*

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SOME practical acquaintance with plants and animals undoubtedly formed the chief content of the mental equipment of prehistoric man, and a considerable knowledge of agriculture and medicine was possessed by the Egyptians and Sumerians nearly 7,000 years ago. So biology has a very ancient pedigree. But biology as the science of life—the study of living phenomena for their own sake in which emphasis is shifted from the practical to the philosophical—really begins with the Greeks, and reaches per saltum a height which was not surpassed, indeed not again attained, for nearly twenty centuries.

Science reaching Greece from the South and East fell upon fertile soil, and in the hands of the Hellenic natural philosophers was organized into coherent systems through the realization that nature works by fixed laws—a conception foreign to the Oriental mind and the cornerstone of all future work because it gave purpose to personal scientific investigation. This attitude of approach is largely responsible for the transformation of the Greek scientific heritage from a collectivistic to an eponymous product.[1] It is not an exaggeration to say that to all intents and purposes the Greeks laid the foundations of the chief subdivision of natural science and, specifically, created biology, though the term biology was first used by Lamarck and Treviranus at the beginning of the nineteenth century.[2]

Aristotle, (384-322 B. C.) the most famous pupil of Plato and dissenter from the Platonic School, represents the highwater mark of the Greek students of nature and is justly called the Father of Natural History. Aristotle's contributions to biology are manifold. He took a broad survey of the existing facts and welded them into a science by relying, to a considerable extent, on the direct study of organisms and by insisting that the only true path of advance lay in accurate observation and description. But mere observation without interpretation is not science. Aristotle's generalizations—his elaboration of broad philosophical conceptions of organisms give to his biological works their perennial significance. Among the facts and supposed facts, and

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[1]E. Clodd: Pioneers of Evolution, 2d ed., 1907, pp. 29-32. C. Singer: Studies in the History and Method of Science, 1917.

[2]Lamarck: Hydrogéologie, 1802. G. R. Treviranus: Biologie, oder Philosophie der lebenden Natur für Naturforscher und Aerzte, 1802-22.

of course there are innumerable crudities if for no other reason than that adequate apparatus and biological technique were of the distant future, there are interspersed questions, answers, theories which show a recognition and remarkable grasp of fundamental biological problems. A study of Aristotle's works shows ancient pedigrees for some of the most "modern" questions of biology, though it is undoubtedly true, as Sachs insists, that one must continually inhibit the tendency to read the present viewpoint into the past, and not assign to earlier writers merits which, if they were alive, they themselves would not claim.

We have not mentioned a single discovery made by Aristotle—and with purpose. Aristotle's position as the founder of biology rests chiefly on his viewpoint and his methods. Plato relied on intuition as the basis of knowledge. Aristotle emphasized observation and induction, insisting that errors arise not from the false testimony of our sense organs but from false interpretations of the data they afford. "We must not accept a general principle from logic only, but must prove its application to each fact; for it is in facts that we must seek general principles, and these must always accord with facts from which induction is the pathway to general laws."[3] But it is not to be imagined that Aristotle always followed his own advice; few great men do—"no pilot can explore unsurveyed channels without a confidence which sometimes leads to disaster." It must be admitted that Aristotle frequently lapsed into unbridled speculation which tended to obscure the methods that time has shown produce the most enduring results, though, as Huxley has well said, "It is a favorite popular delusion that the scientific enquirer is under a sort of moral obligation to abstain from going beyond that generalization of observed facts which is absurdly called 'Baconian' induction. But any one who is practically acquainted with scientific work is aware that those who refuse to go beyond fact, rarely get as far as fact; and any one who has studied the history of science knows that almost every step therein has been made by the 'Anticipation of Nature,' that is, by the invention of hypotheses, which, though verifiable, often had very little foundation to start with: and not infrequently, in spite of a long career of usefulness, turned out to be wholly erroneous in the long run."[4]

While Aristotle's biological investigations were devoted chiefly to animals, his pupil and co-worker, Theophrastus (370-286 B. C.), made profound studies on plants, and the list of botanical facts which he observed and in many cases discovered includes nearly all the rudi-

[3]Aristotle: History of Animals, I, 6. H. F. Osborn: From the Greeks to Darwin, 1894, pp. 16-17, 47. T. H. Huxley: On Certain Errors Respecting the Heart Attributed to Aristotle, 1879 (Coll. Sci. Memoirs, IV, pp. 380-392); G. H. Lewes: Aristotle; a Chapter in the History of Science, 1864, pp. 108-13. T. E. Jones: Aristotle's Researches in Natural Science, 1912. W. Whewell: The Philosophy of Discovery, 1860.

[4]T. H. Huxley: The Progress of Science, 1887 (Coll. Essays, vol. 1, p. 62.)

ments of scientific botany. It is a remarkable fact that many details in plant anatomy, which were figured by the pioneers with the microscope, are to be found in the pages of Theophrastus.[5] He not only laid the foundations of botany, but also gave suggestions of much of the superstructure; an achievement which entitles him to rank as "the first of real botanists in point of time."[6]

With the Greeks, then, biology emerged from the shadows of the past and took concrete form—a fact which apparently the discerning mind of Aristotle appreciated since, though frequently referring to the ancients, he writes:

> I found no basis prepared; no models to copy. . . . . Mine is the first step, and therefore a small one, though worked out with much thought and hard labor. It must be looked at as a first step and judged with indulgence.

Before leaving the Greeks we must mention Hippocrates (460-370 B. C.), the Father of Medicine. Writing a generation before Aristotle, at the height of the Age of Pericles, Hippocrates crystallized the knowledge of medicine into a science, dissociated it from philosophy, and gave to physicians "the highest moral inspiration they have." "To him medicine owes the art of clinical inspection and observation, and he is, above all, the exemplar of that flexible, critical, well-poised attitude of mind, ever on the lookout for sources of error, which is the very essence of the scientific spirit. . . . . The revival of the Hippocratic methods in the seventeenth century and their triumphant vindication by the concerted scientific movement of the nineteenth, is the whole history of internal medicine."[7]

Medicine, the most important aspect of applied biology, is the foster parent of zoology and botany since a large proportion of biological advances have been the work of physicians. Until relatively recently the schools of medicine afforded the only training, and the practice of medicine the chief livelihood for men interested especially in general biological problems.[8] The history of medicine and of biology, as a so-called pure science, are so inextricably interwoven that the consideration of one involves that of the other. Indeed the physicians form the only bond of continuity in biological history between Greece and Rome. The chief interest of the Romans lay in technology, and therefore it is natural that the practical advantages to be gained would ensure the advance of medicine.[9] As it happens, however, two Greek physicians were destined to have the most influence: Dioscorides, (c. 64 A. D.), an army surgeon under Nero, and Galen (131-201 A. D.), physician to the Emperor Marcus Aurelius and his son, Commodus.

Just as Theophrastus established botany as a pure science, so

[5]E. L. Greene: Landmarks of Botanical History, 1909, pp. 52, 53, 140-142.
[6]A. Haller: Bibliotheca Botanica, I, 31.
[7]F. H. Garrison: History of Medicine, 2d ed., 1917, p. 82.
[8]T. H. Huxley: The Connection of the Biological Sciences with Medicine. Nature, 24, 1881, pp. 342-46; (Also in Coll. Essays).
[9]W. Libby: An Introduction to the History of Science, 1917, Chapter 3.

Dioscorides was the originator of the pharmacopoeia, writing, as he did, not only a work which was the first one on medical botany, but one which, gaining authority with age, was the sole standard "botany" for fifteen centuries. Theophrastus was long overshadowed. Most of the botanical writings up to the seventeenth century were annotations on the text of Dioscorides.[10]

Galen was the most famous physician of the Roman Empire and his voluminous works represent both the depository for the anatomical and physiological knowledge of his predecessors, rectified and worked over into a system, and a vast amount of original investigation. Galen was a practical anatomist who described from dissections and insisted on the importance of vivisection and experiment, and therefore may be considered the first experimental physiologist and the founder of experimental medicine. Galen gave to medicine its standard anatomy and physiology for fifteen centuries.[11]

Any consideration of the biological science of Rome would be incomplete without a reference to the vast compilation of fact and fiction, indiscriminately mingled, made by Pliny the Elder (23-79). It was beside the path of biological advance, but long the recognized "Natural History," passing through some eighty editions after the invention of printing. Its prestige was largely due to the fact that it was written in Latin whereas the great works on biological subjects were in Greek.[12]

For all practical purposes we may consider that biology at the decline of the Roman Empire was represented in the works of Aristotle, Theophrastus, Dioscorides, Galen, and Pliny. Even these exerted little influence during the Middle Ages, being saved from total loss for future generations chiefly by Arabian scientists, and in the monasteries of Italy and Britain. We cannot pause to consider the various causes which resulted in the almost complete break in the continuity of learning in general and science in particular during the dormant period in western Europe.[13] Suffice it to say that contributing factors were wars and rumors of wars, the destruction of the libraries of Alexandria, the antagonism of Christian and pagan ideals, and the establishment by the Church, which held the gates of learning, of the written word in place of observation of nature as it is. "Truth and science came to mean simply that which was written, and inquiry became mere interpretation."

In so far as science was taught at all it was from small compilations of corrupt texts of ancient authors interspersed with anecdotes and fables. Under theological influence there arose the oft-quoted

[10]Greene, op. cit., pp. 151-154.

[11]M. Foster: Lectures on the History of Physiology, 1901. Garrison, op. cit., p. 97-101. M. Verworn: General Physiology, English trans., 1899, pp. 8-11.

[12]F. E. Hulme; Natural History Lore and Legend, 1895, pp. 20-29. Greene, op. cit., pp. 155-159.

[13]A. D. White: History of the Warfare of Science with Theology in Christendom, 1898. Clodd, op. cit., p. 34. Russell, op. cit., pp. 124 et seq.

Physiologus,[14] found in many forms and languages, which is at once a collection of natural history stories, and a treatise on the medicinal use of animals and on symbolism. The centaur and the phoenix take their place with the frog and crow in affording illustration of theological texts and in pointing out more or less evident morals. The line of demarkation between the Physiologus and the Bestiaries into which it gradually evolved is ill defined, while the remnants of the latter are incorporated in the early works of the Renaissance encyclopaedists.[15]

So low had science fallen that, strange to say, the scientific Renaissance may be said to owe its origin to the revival of classical learning and to the translation and study of the writings of Aristotle and others which had been under eclipse for a millennium. These were so superior to the existing science, if it may be dignified by that name, that, in accord with the spirit of the time, Aristotle and Galen became the bible of biology. The first works were merely commentaries on the classical authors, but as time went on more and more new observations were interspersed with the old until elaborate and voluminous treatises describing all known forms of plants and animals were produced. In short, the climax of the scientific Renaissance involved a turning away from the authority of Aristotle and an adoption of the Aristotelian method of observation and induction.

Botany was the first to show visible signs of the awakening, probably because of the dependence of medicine on plant products. "All physicians professed to be botanists and every botanist was thought fit to practice medicine." The Hortus Sanitatis, in a way the botanical counterpart of the Bestiaries, gave place to the Herbals.[16] At the hands of the Herbalists of Germany during the sixteenth century, such as Brunsfels, Tragus, Fuchs, and Valerius Cordus, we can trace the evolution of plant description and classification from mere annotations on Dioscorides to well illustrated manuals of the flora of western Europe.[17]

During the same century zoology made abortive attempts to emerge as a science, but the less immediate utility of the subject combined with the difficulty of collecting material and therefore the necessity of more dependence on traveler's tales, all contributed to retard its advance.

One group of naturalists, the Encyclopaedists, so-called from their endeavor to gather all possible information of living things, attempted the impossible. Gleaning from the ancients and adding such materials as they could collect led to the production of huge books of fact and fancy whose value bore no just proportion to the vast expenditure of labor, even in the case of the best—Gesner's Historia Animalium,

[14]White, op. cit. Also, F. Lauchert: Geschichte des Physiologus, 1889.
[15]Hulme, op. cit., pp. 31, 50.
[16]A. Arber: Herbals; their Origin and Evolution. A Chapter in the History of Botany. 1912.
[17]Greene, op. cit., pp. 164 et seq.

which appeared volume by volume between 1551 and 1587, and comprised some 4,500 folio pages of text and wood cuts.[18]

Although Gesner (1516-1565) was without doubt the most learned naturalist of the period and perhaps the best zoologist that had appeared since Aristotle, the direct path to progress was blazed by men whose plans were less ambitious than those of the Encyclopaedists. Thus, contemporaries of Gesner, men who were befriended by him, such as Rondelet (1507-1566) who gave descriptions of the fishes of the Mediterranean based for the most part on his own observations, and Belon (1517-1564) who illustrated the fishes and birds which he saw in France and the Levant, really instituted the zoological monograph which has proved the productive method of biological study.[19]

Even while the Herbalists, Encyclopaedists and Monographers were at work in natural history, making brave attempts to develop the powers of independent judgment which were oppressed to such an extent during the Middle Ages that the very activity of the senses seemed stunted, the emancipator of biology from the thraldom of the ancients appeared in the Belgian anatomist Vesalius (1514-1564). Disgusted with the anatomy of the time which consisted almost solely in interpreting the works of Galen by reference to crude dissections made by barber's assistants, Vesalius set his hand to the task of placing human anatomy on the firm basis of exact observation, and his great work De Humani Corporis Fabrica makes the year 1543 the dividing line between ancient and modern anatomy.[20] Galen's similar attempt failed because his followers made a bible of his work; but with Vesalius, the time was opportune and, in spite of the opposition of his former teacher Jacobus Sylvius and his pupil Columbus, thenceforth anatomical as well as biological investigation in general broke away from the yoke of authority and men began to trust their own eyes. His successor at Padua, Fallopius, says that Vesalius "so shewed me the true path of inquiry that I was able to walk along it still farther than had been done before."

The work of Vesalius is on anatomy, and physiology is treated somewhat incidentally, though it is evident that he was no better satisfied with Galenic physiology than with Galenic anatomy. The complementary work on the side of function came in 1628 with the publication of Harvey's tract, Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus. No rational conception of the economy of the animal organism was possible under the influence of the Galenic system, and it remained for Harvey (1578-1657) to demonstrate by a series of experiments, logically planned and ingenuously executed, that the blood flows in a circle from heart back to heart again, and

[18] L. C. Miall: The Early Naturalists, their Lives and Work, 1912, pp. 47-50.
[19] Miall, op. cit. pp. 40-47.
[20] W. Stirling: Some Apostles of Physiology, 1902, pp. 2-5. M. Foster, op. cit., p. 2.

thus to supply the background for a proper understanding of the dynamics of the organism as a whole. A new picture of the function of the blood was presented which quickly led to the discovery of the lymphatic system, and gave content to the study of the nutrition of the body.[21]

Harvey's use of distinctively quantitative factors is so important in its establishment of the experimental method in biology that his own statement is of great historical interest:

> I frequently and seriously bethought me, and long revolved in my mind, what might be the quantity of blood which was transmitted, in how short a time its passage might be effected, and the like; and not finding it possible that this could be supplied by the juices of the ingested aliment without the veins on the one hand becoming drained, and the arteries on the other hand getting ruptured through the excessive charge of blood, unless the blood should somehow find its way from the arteries into the veins, and so return to the right side of the heart; I began to think whether there might not be a motion, as it were, in a circle. Now this I afterwards found to be true; and I finally saw that the blood, forced by the action of the left ventricle into the arteries, was distributed to the body at large, and its several parts, in the same manner as it is sent through the lungs, impelled by the right ventricle into the pulmonary artery, and that it then passed through the veins and along the vena cava, and so round to the left ventricle in the manner already indicated. Which motion we may be allowed to call circular.[22]

With the work of Vesalius and Harvey, biologists had again laid hold of the great scientific tools—observation, experiment, induction, which since have not slipped from their grasp.

The Microscopists

Even while the marshalling of accurate descriptions of plants and animals was getting under way, and the study of microscopic anatomy and physiology was making rapid strides forward, an event occurred which was destined to make possible modern biology. This was the adaptation of the principle of the spectacles—the invention, probably by Roger Bacon, of convergent lenses, and therefore of the simple microscope. Then came the compound microscope as a development of the telescope at the hands of Galileo about 1610, and by the end of the century simple and compound microscopes were being made by opticians in the leading centers of Europe.[23]

The earliest clear appreciation of the importance of studying nature with instruments which increase the powers of the senses in general and the vision in particular, is found in a remarkable book, the "Micrographia" of Robert Hooke (1635-1703), published by the Royal Society of London in 1665, which is a demonstration of the advantages to be gained by the use of artificial devices of precision in studying

[21] J. G. Curtis: Harvey's Views on the Use and Circulation of the Blood, 1915. T. H. Huxley: William Harvey, Fortnightly Review, 23, 1878 (Also Coll. Sci. Mem., Vol. 4, p. 319).

[22] Harvey: De Motu Cordis et Sanguinis, English trans. by R. Willis, 1848. (See reprint in "Everyman's Library," pp. 55-56.)

[23] Miall, op. cit., p. 136.

nature. "The next care to be taken, in respect to the senses, is a supplying of their infirmities with instruments, and, as it were, the adding of artificial organs to the natural; this in one of them has been of late years accomplished with prodigious benefit to all sorts of useful knowledge, by the invention of optical glasses. . . . . It seems not improbable, but that by these helps the subtiliety of the composition of bodies, the structure of their parts, the various texture of their matter, the instruments and manner of their inward motions, and all the other possible appearances of things, may come to be more fully discovered. . . . . "[24]

Although the work is replete with singular anticipations of the discoveries and inventions of other workers in various branches of science, the biologist's interest is chiefly in Hooke's application of his improved compound microscope to the study of plants and animals which paved the way for the more special, profound, and methodical studies of the contemporary students of nature. In the Micrographia are clearly described and figured for the first time the "little boxes or cells"[25] of organic structure, and his use of the word "cell" is responsible for its application to the protoplasmic units of modern biology. It is fair to say that the influence of the Micrographia permeated the sciences in various directions and the illustrations of microscopic objects were copied for nearly two centuries.[26]

The Micrographia was a mere incident in the varied interests of Hooke, while van Leeuwenhoek (1632-1723) spent a long life in studying nearly everything which he could bring within the scope of his simple lenses. Fascinated with the "world of the infinitely little," with a virgin field before him, and no literature on the subject to divert his energies, he was able year after year to send letters to learned academies, chiefly the Royal Society of London, describing what of necessity were discoveries. He saw the Bacteria—he is the first bacteriologist—the Infusoria—he is the first protozoologist—Yeast cells, Rotifers, Hydra; but the list is too long.[27] However, all of Leeuwenhoek's work is by no means dusultory. He displayed much ingenuity in studying the flow of blood through capillaries of the web of the frog's foot and bat's wing, the viviparous reproduction in aphids, the development of fleas, the dessication of rotifers. And all the time he was looking for evidence against the idea of spontaneous generation, being convinced "it is fully proved that no living creature is produced by corruption or putrefaction."[28] But Leeuwenhoek's contribution which attracted the most interest was his description of spermatozoa. Brought to his attention by a young physician,

[24]Micrographia, preface.
[25]Micrographia, observation XVIII, pp. 112-116.
[26]L. L. Woodruff: Hooke's Micrographia, American Naturalist, 53, 1919.
[27]Miall, op. cit., pp. 200-223. B. W. Richardson: Disciples of Aesculapius, 1900.
[28]Select Works of A. van Leeuwenhoek, edited by S. Hoole, 1800-7.

Hamm, Leeuwenhoek transmitted the discovery to the Royal Society. His imagination, however, outstripped his observations and he thought he saw evidence of a homunculus within the spermatozoon. Thus he came to regard the sperm as the true germ which had only to be hatched, as it were, by the female. He was thus the first of the school of 'spermists' which opposed the idea of the 'ovists' that all is performed in the egg.[29]

The patience of Leeuwenhoek would have been strained to the breaking point by the studies on insect anatomy made by Swammerdam (1637-1680) and eventually brought together in his Biblia Naturae. Instigated largely by the desire to refute the current notion, supported by certain statements of the great Harvey, that insects and similar lower animals are merely masses of organic matter which have been moulded, as it were, into a definite form, and are without complicated internal organs, Swammerdam spent his life in studies on their structure and life histories.[30] Revealing as he did, by the most delicate technique in dissection, the finest details observable with his lenses, Swammerdam not only set a standard for minute anatomy which, with that of his contemporary Malpighi, was not surpassed until the work of Lyonet and others nearly a century later, but also dissipated, for all time, the conception of simplicity of structure in the lower animals. Swammerdam thus quite naturally added one more argument to those of Redi and others against spontaneous generation:

> That vulgar opinion, . . . which ascribes birth and growth of animals to putrefaction and chance, is diametrically opposite to sound reason. . . . in the smallest animals we constantly everywhere find as much order, contrivance, beauty, wisdom, and omnipotence in the Great Architect, as are shown in the viscera of the largest animals. For to these greater animals all others, however minute, are similar in the great respects of brain, nerves, muscles, heart, stomach, intestines, and parts subservient to generation, and to every other useful purpose; so that one might in a manner affirm, that God has created but one animal, though divided into an infinite number of kinds or species, differing from each other in the figures and inflexions, and extensions of their limbs, as likewise in their dispositions, food and manner of living.[31]

Contemporaries of Hooke, Leeuwenhoek, and Swammerdam were two men who may be considered as the pioneer histologists—Malpighi of Bologna and Grew of London. Grew (1641-1712) devoted all his attention to plant structure, while Malpighi, in addition to botanical studies which paralleled Grew's, made elaborate investigations on animals.

The versatility as well as the genius of Malpighi (1628-1694) is illustrated by his studies on the anatomy of plants, the function of leaves, the development of the plant embryo, the embryology of the chick, the anatomy of the silkworm, the structure of glands.[32] Skilled

[29]Phil. Trans. Royal Soc., 142, 1678.
[30]H. Boerhaave: Life of Swammerdam (Preface to the Biblia Naturae) F. C. Miall, op. cit., pp. 174-199. Also Miall's History of Biology, 1911.
[31]Biblia Naturae, English trans. Edited by John Hill, 1758, part 2, p. 71.
[32]Miall, op. cit., p. 145.

in anatomy but with prime interest in physiology, his lasting contribution lies in his dependence on the microscope for the elucidation of problems where structure and function, so to speak, merge—well illustrated by his ocular demonstration of the capillary circulation in the lungs; at once his first and greatest discovery and the first of prime importance ever made with a microscope—since it completed Harvey's work on the circulation of the blood. Malpighi wrote:

"I see with my own eyes a certain great thing. . . . It is clear to the senses that the blood flowed away along tortuous vessels and was not poured into spaces, but was always contained within tubules, and that its dispersion is due to the multiple winding of the vessels."[33]

The microscopists taken collectively created an epoch in the history of biology, so important is the lens for the advancement of the science.[34] Indeed we find that, broadly speaking, its development along many lines during the eighteenth and particularly the nineteenth century has gone hand in hand with improvements in the compound microscope itself and in microscopical technique. Again, the microscopists in general and Malpighi in particular opened up so many new paths of advance that from this period on it is not possible, even in the most general survey, to discuss the development of biology as a whole. The composite picture must be formed by emphasizing and piecing together various lines of work, such as classification, comparative anatomy, embryology, physiology, heredity, and evolution.

Classification

Classification has as its object that of bringing together things which are alike and separating the unlike. It is "discrimination, description, and illustration—the necessary census task which forms the groundwork on which great theories may be built up"[35]—a problem of no mean proportions when a conservative estimate today shows upward of a million species of animals and plants, leaving out of account the myriads of forms represented only by fossil remains. Naturally the earliest classifications were utilitarian, or more or less physiological: edible and harmful, useful and useless, fish of the sea and beasts of the earth. But as knowledge increased, emphasis was shifted to the anatomical criterion of specific differences and thenceforth classification became at once an important aspect of natural history—a central thread both practical and theoretical. Practical, in that it involved the arranging of living forms so that a working catalog was formed which involved nice anatomical discrimination, and therefore the amassing of a large body of facts concerning animals and plants. Theoretical, because in the process botanists and zoologists were impressed, almost unconsciously at first, with the 'affinity' of various

[33]Foster, op. cit., p. 96.
[34]J. Sachs: History of Botany. English translation, 1890, pp. 220-222.
[35]R. L. Praeger, in Oliver's Makers of British Botany, 1913, p. 220.

types of animals and of plants and so were led to problems of their origin.

From Aristotle who emphasized the grouping of organisms on the basis of structural similarities, we must pass over some seventeen centuries, in which the only work of interest was done by the herbalists and encyclopaedists, to the time of Ray (1628-1705) of Cambridge. As a matter of fact, the Theophrastan classification of plants as Trees, Shrubs and Herbs persisted until the end of the seventeenth century. Previous to Ray the term "species" was used somewhat indefinitely, and his chief contribution was to make the word more concrete by applying it solely to groups of similar individuals, which exhibit constant characters from generation to generation. Covering, as Ray's labors did, the classification of both animals and plants, it is probably not an exaggeration to regard him as the seventeenth century precursor of the great Swedish taxonomist, Linnaeus, for whom he paved the way.[36]

Like many another genius, Linnaeus (1707-1778) was a product of his time and, perhaps, one of the very best examples of the fact that "the most original people are frequently those who are able to borrow the most freely"—to see a great deal in what to others appears commonplace. Linnaeus was first and foremost a botanist. Garnering the best the past had to offer in taxonomy and bringing to bear on it his supreme talent for "classifying, coordinating and subordinating," Linnaeus gave botanical students at once a practical method of classification of flowering plants, based chiefly on the number and arrangement of the stamens. At the same time he insisted on brief descriptions and the scheme of giving each kind of organism a name composed of two words, in which the second word indicates the species and the first, the genus, a group of closely similar species. In short, to name an organism is to classify. Linnaeus' success with botanical taxonomy led him to extend the principles to animals and even to the so-called Mineral Kingdom, the latter showing at a glance his lack of appreciation of any genetic relationship between species.[37]

Indeed the terms genus and species to Linnaeus expressed a transcendental affinity since he believed that species, genera, and even higher groups represented distinct, consecutive thoughts of the Creator. Accordingly, the ultimate goal of taxonomy was to determine the so-called scala naturae. Thus, Linnaeus crystallized two dogmas—constancy and continuity of species—which permeated biology and reached, in slightly different form, their high water mark, indeed a reductio ad absurdum, in Agassiz's Essay on Classification a century later—as fate would have it, just a year before Darwin's Origin of Species.[38]

[36]S. H. Vines: Robert Morrison and John Ray, in Oliver's Makers of British Botany, 1913, p. 9.
[37]J. Sachs, op. cit., p. 108. F. C. Miall: History of Biology, p. 66.
[38]Miall, op. cit., p. 157.

Though today Linnaeus' conception of fixity has been replaced by modifiability of species; the affinity which he recognized and expressed in transcendental terms has given place to similarity based on descent, and his artificial classifications have been superceded by natural classifications, which express, or attempt to express, this genetic connection between species—nevertheless, his greatest works, the Systema Naturae and Species Plantarum created an epoch in biological history, and are by common consent the base line of priority in zoological and botanical nomenclature.[39]

An aftermath of Linnaeus' labors must be mentioned. Naturalists in general and botanists in particular were so captivated with the facility which the Linnean system afforded for cataloging, that collecting and naming became a dominant note for nearly a century. The few who employed microscope and scalpel are outstanding figures on the path to progress.[40]

Comparative Anatomy

The first step toward scientific classification was made, as we have seen, by Aristotle in emphasizing anatomical characters as taxonomic criteria, so that to all intents and purposes classification implies comparison of structural details. Indeed Aristotle recognized the unity of structural plan throughout the chief animal groups, and in reference to man he says "whatever parts a man has before, a quadruped has beneath; those that are behind in man form the quadrupeds back." Not only did he appreciate homology, but also correlation of parts and division of labor in the economy of the animal body.[41] And Theophrastus approached plant morphology in the same philosophical spirit—witness his recognition of the flower as a metamorphosed leafy branch.[42] But it probably would be reading too much into the past to assign the origin of comparative anatomy of animals in the modern sense of the term to Greek, Roman, or early Renaissance science, since description rather than comparison was the key-note. The same may be said of the anatomical work of Vesalius, Harvey, and Malpighi though the latter compared the microscopic structure of various organs, and in his Anatomy of Plants, which shares with Grew's Anatomy the honor of founding vegetable histology, emphasizes the importance of the comparative method. Owing to the less marked structural differentiation of plants in comparison with animals, plant anatomy does not lend itself as readily to descriptive analysis so that an epoch in the study of comparative anatomy is less defined in botany

[39]Systema Naturae, 1735, 10 ed., 1758. Species Plantarum, 1753.

[40]F. W. Oliver: Makers of British Botany, 1913, p. 193. For the point of view of the early part of the nineteenth century, cf. W. Swainson: On the Study of Natural History, 1834.

[41]E. S. Russell: Form and Function; A Contribution to the History of Animal Morphology, 1917, Chapter 1.

[42]Greene, op. cit.

than in the sister science. Therefore both reason and expediency warrant confining our attention to the comparative anatomy of animals.

Probably the first consistent attempt to make a comparative study of the form and arrangements of the parts of animals is represented in a volume published in 1645 by Severinus (1580-1656) of Naples in which he concluded that many vertebrates are constructed on the same plan as man, though Belon, nearly a century earlier, figured and compared the skeletons of bird and man side by side "in the same posture, and as nearly as possible bone for bone."[43] Tyson (1650-1708) of Cambridge at the end of the seventeenth century definitely instituted the monographic treatment of comparative morphological problems in his study of the anatomy of man and monkeys.[44]

Comparative anatomy, however, as a really important aspect of biological work, in fact, as a science in itself, was the result of the life work of Cuvier (1769-1832) of Paris during the first quarter of the last century. It is true that his immediate predecessors, such as John Hunter (1728-1793), the founder of the Hunterian Collection, the nucleus of the anatomical Museum of the Royal College of Surgeons in London, Camper (1722-1789) of Groningen, and Vicq d'Azyr (1748-1794) of Paris, added synthesis to analysis and reached a broader view-point in anatomical study, but Cuvier's claim to fame rests on the remarkable breadth of his investigations—his grasp of the comparative anatomy of the whole series of animal forms.[45] And not content merely with the living, he made himself the first real master of the anatomy of fossil vertebrates and as such is the founder of paleontology.[46]

Cuvier's position in the history of anatomy is largely due to his emphasizing, as Aristotle had done before him, the functional unity of organisms—that the interdependence of organs results from the interdependence of function and that structure and function are two aspects of the living machine which go hand in hand. Cuvier's famous principle of correlation—"Give me a tooth," said he, "and I will construct the whole animal"—is really an outcome of this viewpoint. Every change of function involves a change in structure and therefore, given extensive knowledge of function and of the interdependence of function and structure, it is possible to infer from the form of one organ that of most of the other organs of an animal. "In a word, the form of the tooth implies the form of the condyle; that of the shoulder blade that of the claws, just as the equation of a curve implies all its properties."

[43] F. C. Miall: History of Biology, pp. 18-19.
[44] Cf. Garrison, op. cit., p. 240.
[45] Cf. Russell, op. cit., Chapter 3.
[46] T. H. Huxley: The Rise and Progress of Paleontology, Nature, 24, pp. 452-55, 1881. (Also Coll. Sci. Mem. Vol. 4). O. C. Marsh: History and Methods of Paleontological Discovery, Presidential address, Amer. Assn. Adv. Sci., 1879.

Although Cuvier undoubtedly allowed himself to exaggerate his guiding principle until it exceeded the bounds of facts, he was above all in his science and philosophy a hard-headed conservative and autocrat. He opposed with equal vigor the influence of the Naturphilosophie of Schelling and his school with its transcendental anatomy, Platonic archetypes and the like, as well as the evolutionary speculations of Lamarck and his school. From the vantage points of today we know that in one case he was right and in the other wrong—though in so far as the facts then extended, his opposition was justified in both cases.

Cuvier's immediate successors in France were Milne-Edwards and Lacaze-Duthiers; in Germany, Meckel, Rathke, Müller, and Gegenbaur; in England, Owen and Huxley, and in America, Agassiz, Cope, and Marsh Among these, Owen (1804-1892) perhaps demands special mention. At once a peculiar combination of Cuvierian obstinacy in regard to facts and of transcendental imagination, Owen spent a long life dissecting with untiring patience and skill a remarkable series of animal types, as well as in reconstructing extinct forms from fossil remains. Aside from the facts accumulated, probably his greatest contribution was making concrete the distinction between homologous and analogous structures, which has been of the first importance in working out the pedigrees of plants as well as animals—though Owen himself took an enigmatical position in regard to organic evolution.[47]

Physiology

Anatomy emphasizes the static and physiology the kinetic aspect of the organism, though, as we have seen, structure without function is a lifeless subject and function without structure is an impossibility, since, in Huxley's happy phraseology, physiology is the mechanical, and he would now add, chemical engineering of the living organism.

Animal and plant physiology was discussed by Aristotle, but as might be expected since physiology is more dependent than anatomy upon progress in other branches of science, with less happy results. Similarly, Galen was hampered in his attempt to make physiology a distinct department of learning based on a thorough study of anatomy, and the corner stone of medicine. Like Aristotle he attempted to develop a picture of the modus operandi of the organism, and with such success that fate foisted it upon uncritical generations through fifteen centuries. The worst of it was not that it was nearly all wrong, but that to question Galen's physiology or anatomy was little less than sacrilege until the labors of Vesalius and Harvey brought a realization that Galen had not quite finished the work.[48]

[47]Life of Richard Owen, by his grandson, 1894, vol. 2, pp. 89-96. Also, Essay on Owen's Position in Anatomical Science by T. H. Huxley, in above work.

[48]Foster, op. cit., p. 12.

Neither Vesalius nor Harvey made an attempt to explain the workings of the body by appeal to so-called physical and chemical laws; and for good reason. Chemistry had not yet thrown off the shackles of alchemy and taken its legitimate place among the elect sciences, while during Harvey's lifetime, under the influence of Galileo, the new physics arose. But by the end of the seventeenth century both physics and chemistry, aided by the philosophical systems of Bacon and Descartes, had forced their way into physiology and split it into two schools: the iatro-mechanical founded by Borelli (1608-1679), who by incisive physical methods attacked a long series of problems, frequently with brilliant results; and the iatro-chemical school, which developed from the influence of Franciscus Sylvius (1614-1672) as a teacher rather than as an investigator.[49]

This awakening brought a host of workers into the field and the harvest of the century was garnered and enriched by Haller (1708-1777), the "abyss of learning" of the time, in a comprehensive treatise which at once indicated the erudition and critical judgment of its author and established physiology as a distinct and important branch of biological science, rather than a mere adjunct of medicine.[50] Great as was this contribution of Haller in crystallizing physiology and setting the dividing line between the old and the modern, unfortunately the weight of the author's authority was ranged in favor of two theories which were, in crude form, attracting the attention of biologists—the idea of special vital force and the preformation theory of development.

Perhaps the most significant lines of advance in Haller's century were in setting the physiology of nutrition and respiration—both of which waited upon the work of the chemists—well upon their way toward modern form. Réaumur (1683-1757) of Paris, and Spallanzani (1729-1799) of Pavia may be singled out for their exact studies of gastric digestion which, against the background of the pioneer work during the previous century by van Helmont (1477-1644), Sylvius (1614-1672), Stensen (1638-1686), de Graaf (1641-1673), Peyer 1653-1712), and Brunner (1653-1727), established solution of the food as the main factor in digestion, though it was not clear how these changes differed from ordinary chemical ones. So physiologists of a vitalistic turn of mind cloaked their ignorance under the term "animalization," and left for eighteenth century investigators the establishment of the fact that food in passing along the digestive tract runs the gamut of a series of complex chemical substances, or enzymes, each of which has its part to play in putting the various constituents of the food into such a form that they can pass to the various cells of the body.[51]

[49]Foster, op. cit., Chapters 3 and 6.
[50]A. Haller: Elementa Physiologiae Corporis Humani, 1757.
[51]W. B. Johnson: History of the Progress and Present State of Animal Chemistry, 1803.

On the side of respiration a somewhat closer approach was made toward a true understanding of the process, but there was a better foundation on which to build. The Galenic notion that respiration is a process of refrigeration—a getting rid of the innate heat of the heart and of fuliginous vapors—had been superceded, through the efforts of Harveyan experimentalists—the chemist Boyle (1627-1691), the versatile genius Hooke, the physician Lower (1631-1690), and the lawyer-chemist Mayow (1643-1679). The climax only awaited the overthrow of the Stahlian phlogiston theory, which presented an inverted picture of combustion, and the actual discovery of oxygen. This came in the work of Black, Priestley (1733-1804), Lavoisier (1743-1794), and Girtauner (1760-1800) which made it clear that the chemical changes taking place in respiration involve essentially a process of combustion, and it chiefly remained for later work to show that this takes place in the tissues rather than in the lungs.[52]

Enough perhaps has been said to indicate the trend of physiology away from the maze of Galenic spirits in which science lost itself, toward the modern atmosphere of science with its *working hypothesis*, that life phenomena are an expression of a complex interaction of physico-chemical laws which do not differ fundamentally from the so-called laws operating in the inorganic world, and that the economy of the organism is in accord with the law of the conservation of energy —probably the most far reaching generalization of science during the past century. Although it is difficult to discriminate, certainly the names of Liebig, Wöhler (1800-1882), the brothers Weber, Ludwig (1816-1895), Helmholtz (1821-1894), Müller (1801-1858) and du Bois-Reymond (1818-1896) in Germany; Dumas (1800-1884), Magendie (1783-1855) and Bernard (1813-1877) in France; Donders (1818-1889) in Holland; and Hall (1790-1857) in England were, individually and collectively, chiefly responsible for the reformation of physiology.[53]

Most of the firm foundation on which physiology of animals rests today has been built up by work on vertebrates, though since the middle of the nineteenth century, when the versatile Müller showed the value of studying the physiology of higher and lower animals alike, the science of comparative physiology may be said to have been established.[54] Perhaps it is not an exaggeration to say that the tendency to focus evidence, in so far as possible, from all forms of life on general problems of function represents the present trend of physiological enquiry.

[52] J. Loeb: Dynamics of Living Matter, p. 7. O. Hertwig: The Growth of Biology in the Nineteenth Century, Smithsonian Report, 1900, pp. 461-78.
[53] M. Verworn: General Physiology, English trans., 1899, pp. 16-20. Stirling, op. cit., p. 106.
[54] P. B. Hadley: Johannes Müller, Popular Science Monthly, 1908.

The less obvious structural and functional differentiation of plants retarded progress in plant physiology as it did in plant anatomy. Probably of most historical, and certainly of most general interest is the development of our knowledge of the nutrition of green plants.

Aristotle's notion that the food of plants is prepared for them in the ground was still prevalent at the end of the sixteenth century when Cesalpino, the most philosophic botanist of his day, thought that food enters and passes through vessels and fibers of plants much as oil in a lamp wick, and Jung conceded that plants are not mere passive absorbers of ready-made food, but possess the power of selection from the soil the ingredients needed. Van Helmont (1577-1644), on the border line between alchemist and chemist, who precociously brought to bear the chemical point of view on animal physiology, made the first experiment in plant nutrition on record. He planted a small tree in a large vessel and weighed it. Then after five years, during which time it had only been supplied with water, he found that it had increased some thirty fold in weight and "not suspecting that the plant drew a great part of its materials from the air was forced to exaggerate the virtues of rain-water."[55] Malpighi, however, from his studies on plant histology, gave the first hint of the fact of supreme importance that the crude sap, which enters by the roots, is carried to the leaves where, by the action of sunlight, evaporation, and some sort of a fermentation it is "digested" and then distributed as food to the plant as a whole. But, it is Hale (1677-1761) to whom the botanist looks as the Harvey of plant physiology, for in his Vegetable Statics, published in 1727, he laid the foundations of the physiology of plants by making "plants speak for themselves through his incisive experiments." For the first time it became clear that green plants derive an important element of their food from the atmosphere, and also that the leaves play an active rôle in the movements of fluids up the stem and in eliminating superfluous water through evaporation.[56]

Still the picture was incomplete, and so it remained until the biologist had recourse to further data from the chemist. In 1779 Priestley, the discoverer of oxygen, showed that this gas under certain conditions is liberated by plants. This fact was seized upon by Ingen-Housz (1730-1799) who demonstrated that carbon dioxide from the air is broken down in the leaf during exposure to sunlight, the plant retaining the carbon and returning oxygen—the process of carbon-getting being quite distinct from that of respiration in which carbon dioxide is eliminated. It remained then for de Saussure to show, by quantitative studies of the plant's income, that, in addition to the fixation of carbon, the elements of water are also employed while from the soil various salts including the element nitrogen are obtained. But

[55]Thomson, The Science of Life, p. 70.
[56]F. Darwin: Stephen Hales, in Makers of British Botany, 1913, p. 65.

it was nearly the middle of the last century before the influence of Liebig (1803-1873) and the incisive experiments of Boussingault established the fundamental part played by the chlorophyll of the green leaf in making certain chemical elements available to animals. The realization of the cosmical function of green plants—the link they supply in the circulation of the elements in nature—is a landmark in biological progress, and we may leave the subject here since, except for details in regard to some of the more evident chemical products of photosynthesis and the influence of external factors, the matter still stands essentially where it was in de Saussure's day.[57]

Histology

Studies on the physiology of plants and animals naturally involved the progressive analysis of the physical basis of the phenomena under consideration, but the Aristotelian classification of the materials of the body into unorganized substance, homogenous parts or tissues, and heterogenous parts or organs practically represents the level of analysis until the beginning of the last century. It is true, as we have mentioned, that Hooke in 1665 discovered that cork tissue under the microscope seemed to be composed of little boxes or "cells," and somewhat similar though more extensive observations were made by the contemporary students of the microscope. But another century had nearly elapsed before these microscopic elements were looked at from the point of view of their relation to the development of organisms. Wolff (1733-1794) in 1759 attempted to show the falsity of the prevailing idea that all organisms are preformed in the germ and that the adult state is attained merely by an unfolding and enlarging, by a critical study of the development of animals and plants.[58] And he not only proved his point but also showed that both plants and animals in early developmental stages show a similar fundamental structure, "since every organ is composed at first of a little mass of clear, viscous, nutritive fluid, which possesses no organization, but is at most composed of globules. In this semi-fluid mass cavities are now developed; these, if they remain round or polygonal, become the subsequent cells; if they elongate, the vessels; and the process is identically the same, whether it is examined in the vegetating point of a plant, or in the young budding organs of an animal." But Wolff's refutation of preformation, chiefly through the opposition of Haller, proved abortive, and his observations on cells were so far ahead of the times that they had but slight influence on biological advance. It was not until the revival of interest in plant anatomy early in the last century that the cell became a particular object of study—and still it

[57] H. A. Spoehr: The Development of Conceptions of Photosynthesis since Ingen-Housz, Scientific Monthly, 9, 1919, p. 32.

[58] C. F. Wolf: Theoria Generationis, 1759. W. M. Wheeler: Wolff and the Theoria Generationis, Woods Hole Biol. Lectures, 1898, pp. 265-284.

was the cell wall rather than the contents on which attention was fixed. Then the English botanist Brown discovered the cell nucleus in 1831,[59] quickly followed by the classic investigations of the botanist Schleiden (1804-1881) and the zoologist Schwann (1810-1882), published in 1838 and 1839,[60] which taken together clearly showed that all organisms are composed of units or cells which are at once structural entities and centers of physiological activities. Each cell carries on a double life; one a quite independent and self-contained life; the other a dependent life in so far as the cell has become an integral part of the organism. The life of the organism is the life of the individual cells which compose it. And further, not only are all organisms congeries of cells, but the egg is a cell and the development of animals and plants consists in the multiplication of this initial cell into the multitude of different kinds which constitute the adult: "The elementary parts of all tissues are formed of cells in an analogous, though very diversified manner, so it may be asserted that there is one universal principle of development for the elementary parts of organisms, however different, and that this principle is the formation of cells."[61]

Unquestionably the launching of the cell theory represents one of the greatest generalizations in biology, and only needed for its consummation the full realization that the viscid, jelly-like material, which zoologists interpreted as the true living matter of animals, and the quite similar material, which botanists considered the true living part of plants, are practically identical. This conception was grasped in the early sixties by Schultze (1825-1874) in the formulation of the protoplasm theory, and thenceforth not only morphological elements —cells—but also the material of which they are composed—protoplasm —was recognized as fundamentally the same in all living beings. Indeed, the realization of a common physical basis of life in both plants and animals—a common denominator to which all vital phenomena are reducible—gave content to the term biology and created the science of life in its modern form.[62]

Embryology

The enunciation of the cell theory came, as we have seen, from combined studies on the adult structure and on the development of plants and animals from the germ or egg, and accordingly implies that the science of embryology has a history of its own. As a matter of fact, Aristotle discussed the wonder of the beating heart in the hen's egg after three days' incubation, but there the subject practically rested

[59]J. B. Farmer: Robert Brown, in Makers of British Botany, 1913, p. 119.
[60]M. J. Schleiden: Ueber Phytogenesis, 1838. T. Schwann: Mikroscopische Untersuchungen ueber die Uebereinstimmung inder Structur und dem Wachstum der Thiere und Pflanzen. English translations by H. Smith, 1847.
[61]Schwann, op. cit., English trans. p. 165.
[62]E. B. Wilson: The Cell in Development and Inheritance, 2d ed., 1900. Verworn, op. cit.

until Fabricius (1537-1619), early in the seventeenth century, published a treatise which illustrated the obvious sequences of events within the hen's egg to the time of hatching.[63] This beginning was built upon by a pupil of Fabricius, the celebrated Harvey, who added many details of interest and insisted, as Aristotle had before him, that the embryo arises as a gradual differentiation of unformed material of the egg.[64]

However, little progress in embryology was possible without the microscope which was first applied to the problem by the versatile Malpighi, in two treatises sent to the Royal Society in 1672.[65] One has but to study his splendid series of illustrations to realize how animal development was placed upon a plane so advanced that for over a century it was unappreciated. One conclusion of Malpighi, however, was seized upon by contemporary biologists. Apparently, unbeknown to him, some of the eggs which he studied were slightly incubated so that he thought traces of the future organism are preformed in the egg. This error, coupled, for example, with Swammerdam's observation of the fact that parts of the adult insect are delineated in the larva ready to pupate, crystallized the preformation theory which denied all true development or epigenesis, as advocated by Aristotle and Harvey, and held that the future adult characters pre-exist in miniature in the egg. Even the acute observations of Wolff in his embryological classic, to which we have referred, failed of fruition since it negated the preformation idea which, in the years that had elapsed since Malpighi, had become the dominant question in embryology. Indeed the theory was carried to a reductio ad absurdum by Haller, Bonnet (1720-1793) and others who accepted the logical conclusion that:

> Each seed includes a plant: that plant, again,
> Has other seeds, which other plants contain:
> Those other plants have all their seeds; and those,
> More plants, again, successively inclose.
> * * * * * * * * *
> So Adam's loins contain'd his large posterity,
> All people that have been, and all that e'er shall be.
>
> Amazing thought! what mortal can conceive
> Such wond'rous smallness! Yet we must believe
> What reason tells: for reason's piercing eye
> Discerns those truths our senses can't descry.

So Baker expressed it in one of the few departures from prose permitted in the Philosophical Transactions of the Royal Society.[66]

The truth of the matter is that the time was not ripe for theories of development. The preformationists were wrong but so were Aristotle, Harvey, and Wolff who went to the other extreme and denied all egg

[63]Locy, op. cit., p. 43. Russell, op. cit., p. 113.
[64]W. Harvey: Exercitationes de Generatione Animalium, 1651.
[65]Locy, op. cit., p. 202.
[66]H. Baker: The Microscope Made Easy, 2d ed., 1743, p. 252.

organization and therefore tried to get something out of nothing. It remained for the present generation of embryologists to work out many of the details of the origin of the germ cells and their organization, and to reach a level of analysis deep enough to suggest how "the whole future organism is potentially and materially implicit in the fertilized egg cell," and thus that "the preformationist doctrine had a well concealed kernel of truth within its thick husk of error."[67]

The real step to progress, Baker's implicit confidence in "reason" to the contrary, came in the accurate and comprehensive studies of von Baer (1792-1876) published in the thirties of the last century.[68] Taking his material from all the chief groups of higher animals von Baer founded comparative embryology. Among his achievements may be mentioned the clear discrimination of the chief developmental stages, as cleavage of the egg, germ layer formation, tissue and organ differentiation; the importance of the facts of development for classification, and the discovery of the egg of mammals. His observations on the origin and development of the germ layers, which afforded the key to many general problems of morphogenesis, and his emphasis on the resemblance between certain embryonic stages of higher animals and the adult stages of lower forms, were exaggerated and crystallized by his successors, under the influence of the evolution theory, as the germ layer theory and the recapitulation theory, or von Baer's law. Both were of the greatest importance in stimulating research for half a century—and if the present generation has not inherited its forebears' implicit faith in the theories, it at least has profited immensely by the facts they accumulated.[69]

From every point of view von Baer created an epoch in embryology synchronous with the formulation of the cell theory by Schleiden and Schwann, and it thenceforth became the problem of the embryologist to interpret development in terms of the cell. Time will not permit us to follow the establishment of the fact that the egg and the sperm are really single nucleated cells; that fertilization consists in the fusion of egg and sperm and the orderly arrangement of their chief nuclear contents, or chromosomes; that the new generation is the fertilized egg since every cell of its body as well as every chromosome in every cell is a lineal descendant by division from the egg, and so from the germ cells which united at fertilization to form it. Such, however, are the chief results of cytological study since von Baer; but embryologists have not been content to employ merely the descriptive method, and the

[67]Thomson, op. cit. C. O. Whitman: Woods Hole Biological Lectures, 1894, pp. 205-272. E. B. Wilson: The Problem of Development, Science, 21, 1905, pp. 281-294.

[68]K. E. von Baer: Ueber Entwickelungsgeschichte der Thiere. Beobachtung und Reflexion, 1828-37. Cf. Huxley: Philosophical Zoology Selected from the Works of K. E. von Baer, in Scientific Memoirs, February and May, 1853.

[69]Locy, op. cit., pp. 214-222.

dominant note of the most modern research under the influence of Roux is physiological—the experimental study of the significance of fertilization, the dynamics of cell division, the basis of differentiation, the effect of environmental stimuli, and so on.[70]

Genetics

It is but natural that the study of inheritance could be little more than a groping in the dark until embryology, under the influence of the cell theory, afforded a body of facts which clearly indicated that the fertilized egg is typically the sole bridge of continuity between successive generations. Indeed the present science of genetics has a history confined solely to post-Darwinian times and mostly to this century.

Although clearly suggested by a number of workers, the conception of the continuity of the germ cells—or germ plasm—was first forced upon the attention of biologists and given greater precision by Weismann (1834-1914) in a series of essays culminating in 1892 in his volume entitled The Germ Plasm. He identified the chromatin material which constitutes the chromosomes of the cell nucleus as the specific bearer of hereditary characters, and emphasized a sharp distinction between the cellular derivatives of the fertilized egg—on the one hand, the somatic cells which by division and differentiations build up the body of a higher plant or animal; and on the other, the germ cells which are destined to play but little part in the life of the individual which bears them, but instead are to be liberated and give rise to the next generation. The importance of this distinction can hardly be over emphasized for at once it makes clear that, for all practical purposes, the bodily characteristics of an individual are negligible from the stand point of heredity, since the offspring are descendants not from the body cells, but from the germ cells which it carries—and these in turn from the germ cells of the preceding generation. As Weismann insisted, this view makes it difficult to conceive how modifications of the soma can so specifically affect the germ cells which it bears that the latter can reproduce the modifications—in other words that so-called "acquired characters" can not be inherited. And there is no satisfactory evidence that such characters are inherited. The practical bearings of this conclusion are obviously of the highest importance, lying as they do at the very root of many questions in regard to the factors of evolution, not to mention such practical ones as education and eugenics.

While this viewpoint has been gradually gaining content and precision, the science of heredity has been advancing not only by exact studies of the structure and physiology of the germ cells, but also by statistical investigations of the results of heredity—the various characters of animals and plants in parent and offspring.

[70] Wilson, op. cit.

The first studies of this type which attracted the attention of biologists were made by Galton (1822-1911), who in the eighties and nineties of the last century amassed a large amount of data in regard, for example, to the stature of children with reference to that of their parents, and formulated his well known "laws" of inheritance.[71] But the epoching making work which eventually created the science of genetics was that of an Austrian monk, Gregor Mendel (1822-1884), who combined in a masterly manner the experimental breeding of pedigreed strains of plants and the statistical treatment of the data thus secured in regard to the inheritance of sharply contrasting characters, such as the flower color in sweet peas. Mendel's work was published in 1865 in an obscure natural history periodical[72] and he himself abandoned his teaching and research to become the Abbot of his monastery. Thus terminated prematurely the productive work of one of the epoch makers of biology, and the now famous "Mendelian laws" of inheritance were unknown to science until 1900 when other biologists, coming to similar results, unearthed his forty-year-old paper. We can pause only to say that the fundamental principle of the segregation of the genes of the alternative characters within the germ cells, which Mendel's work indicated, has been extended to other plants and to animals, and from being, as at first thought, a principle of rather limited application, now seems to be the key to all inheritance. And the present results are extremely convincing because cytological studies on the architecture of the chromosome-complex of the germ cells keep pace and afford a picture of the physical basis—of the mechanism by which the segregation and distribution of characters by the Mendelian formula takes place.[73] Such is the deeply hidden germ of truth in the old preformation theories!

Origin of Life

With our present conception of the complexities of organisms it is difficult to realize that up to the seventeenth century naturalist and layman saw nothing more incongruous in the spontaneous origin of nearly all kinds of plants and animals than does the boy of today who believes that horse hairs soaked in water are transformed into worms. Even Aristotle thought that certain of the vertebrates, such as eels, arose spontaneously, and Harvey accepted the same view of the origin of many forms of life. It remained for Redi (1626-1698) to lay aside discussion for experiment. By protecting decaying meat from contamination by flies he demonstrated that these insects are not developed from the flesh and that the apparent transformation of meat into maggots

[71]F. Galton: Natural Inheritance, 1889.

[72]G. J. Mendel: Versuche über Pflanzen-Hybriden, Verhandlungen des naturforschenden Vereines in Brünn, Bd. 4, 1865.

[73]T. H. Morgan: The Physical Basis of Heredity, 1919.

is due solely to the eggs of flies being deposited thereon.[74] But the time-honored doctrine was not overthrown by this experiment or the long series which Redi made, for the presence of parasites within certain recondite parts of higher animals baffled Redi himself, while improvements in the microscope soon revealed a microcosm whose origin seemed plausibly explained as spontaneous. Biogenesis, or all life from preexisting life, was placed on a secure foundation only within the past sixty years by the working out of the remarkably complex life histories of internal parasites and by the classical demonstrations of Pasteur and others that micro-organism are not the result but the cause of decay; a fact which is at the basis of and is attested by the methods now universally in use in food preservation and aseptic surgery—to mention but two instances.[75] The vicissitudes of the doctrine of biogenesis—" la génération spontanée est une chimère," wrote Pasteur—is an eloquent illustration of the aphorism of the old London microscopist that "the likeliest method of discovering truth is by the observations and experiments of many upon the same subject."[76]

Organic Evolution

Since we have every reason to believe that all life now arises from preexisting life and has done so since matter first assumed the living state, it apparently follows that the stream of life is continuous from the remote geological past to the present and that all organisms of today have an ancient pedigree. This leads us to a question which has interested and perplexed thinking men of all times, how things came to be as they are today? It was the Greek natural philosophers who projected the idea of history into science and attempted to substitute a naturalistic explanation of the Earth and its inhabitants for the established theogenies, and thus started the uniformitarian trend of thought which culminated in the establishment of organic evolution during the past century.

Again it is Aristotle who is singled out among the Greeks for his combination of sound philosophy and induction which reaches no higher expression than in his statements regarding the relationships of organisms. He says, in substance: Although the line of demarcation is broadly defined, yet nature passes by ascending steps from one to the other. The first step is that of plants; which, compared with animals, seem inanimate. The second step nature takes is from plants to plant-animals, the zoophytes. The third step is the development of animals, which arise from an increased activity of the vital principle,

[74]F. Redi: Esperienze Intorno alla Generazione Degl'Insetti, 1668. English trans. 1909.

[75]T. H. Huxley: Biogenesis and Abiogenesis. Presidential Address, British Assn. Adv. Sci., 1870. Collected Essays, Vol. 8, L. L. Woodruff: The Origin of Life, in the Evolution of the Earth and Its Inhabitants, R. S. Lull, editor, 1918.

[76]Baker, op. cit., p. V.

resulting in sensibility; and with sensibility, desire; and with desire, locomotion. Man is the head of animal creation. To him belongs the God-like nature. He is preeminent by thought and volition. But although all are dwarf-like and incomplete in comparison with man, he is only the highest point of one continuous ascent.[77]

Broadly speaking, Aristotle apparently held substantially the modern idea of the evolution of life from a primordial mass of living matter to the highest forms, and believed that evolution is still going on—the highest has not yet been attained. In looking for the effective cause of evolution Aristotle rejected Empedocles' hypothesis of the chance play of forces, which embodied in crude form the idea of the survival of the fittest, and substituted secondary natural laws to account for the fact that "Nature produces those things which, being continually moved by a certain principle contained in themselves, arrive at a certain end." As Osborn points out, Aristotle's rejection of the hypothesis of the survival of the fittest to account for adaptations of organisms was a sound induction from his necessarily limited knowledge of nature—but had he accepted it he would have been "the literal prophet of Darwinism."[78]

Although the thread of continuity of evolutionary thought is not broken from Aristotle to the present, no historical interest will be served in following the poetical expression by Lucretius, the discussion at once broad and narrow of the most liberal medieval Churchmen, the "Arab philosophy—a system of Greek thought expressed in a Semitic tongue and modified by Oriental influences," or the vagaries of the Renaissance naturalists and speculative evolutionists, who, with a minimum of fact and a plethora of imagination were the worst enemies of the evolution idea. In truth, the great natural philosophers from Bacon and Leibnitz to Kant and Hegel laid the broad foundation for our modern attack on evolution, but from the strictly biological viewpoint, two Frenchmen, Buffon and Lamarck, and two Englishmen, Erasmus Darwin and his grandson, Charles Darwin, stand preeminent, and the greatest is Charles Darwin.

Buffon (1707-1778) was a peculiarly happy combination of parlor entertainer and scientist—entertaining by each new volume of his great Natural History the social set of Paris, and instructing them at the same time. And it was largely between the lines of his Natural History that Buffon's evolutionary ideas found expression; but expressed they are, though sometimes difficult to decipher—beyond the ken, Buffon hoped, of the censor and dilettant, for apparently he was not of martyr stuff.[79] It is not strange, therefore, that there are some differences of opinion amongst biologists today as to just how much

[77]Lewes, op. cit., pp. 189-96. Osborn, op. cit., p. 48.
[78]Osborn, op. cit., pp. 55-57.
[79]S. Butler: Evolution Old and New. 3d Edition, 1911, p. 78. A. O. Lovejoy: Buffon and the Problem of Species, Pop. Sci. Monthly, 1911.

weight is to be placed on some of Buffon's statements, but certainly it is not exaggerating to ascribe to him not only the recognition of the factors of geographical isolation, struggle for existence, artificial and natural selection in the origin of species, but also, which is equally important, the propounding of a theory of the origin of variations. He thought that the direct action of the environment brings about modifications of the structure of animals and plants and these are transmitted to the offspring.[80]

When Buffon's influence was at its zenith, Erasmus Darwin (1731-1802), a successful medical practitioner, expressed consistent views on the evolution of organisms in several volumes of prose and poetry.[81] Although a contemporary critic in the Edinburgh Review remarked that Darwin's "reveries in science have probably no other chance of being saved from oblivion, but by having been married to immortal verse," today biologists recognize him as the anticipator of Lamarck's doctrine that variations spring from within the organism through its reaction to environmental conditions. "All animals undergo perpetual transformations which are in part produced by their own exertions, in consequence of their desires and aversions, of their pleasures and their pains, or of irritations, or of associations; and many of these acquired forms or propensities are transmitted to their posterity."[82]

While Cuvier was extending and synthesizing the knowledge of anatomy of living and extinct forms and founding the so-called school of facts, his fellow-countryman Lamarck (1744-1829), on the basis of work first on plants and then on animals, carried on in fearless manner the evolutionary inspiration of Buffon and Erasmus Darwin (though the latter's works may not have been known to him), and established the coterie of evolutionists in Paris each of whose essays Cuvier hailed as a "new folly." Lamarck developed with great care the first complete and logical theory of organic evolution, and is the one outstanding figure in biological uniformitarian thought between Aristotle and Charles Darwin. "For nature," he writes, "time is nothing. It is never a difficulty, she always has it at her disposal; and it is for her the means by which she has accomplished the greatest as well as the least of her results. For all the evolution of the earth and of living beings, nature needs but three elements—space, time, and matter."[83]

In regard to the factors of evolution, Lamarck emphasized the indirect action of the environment in the case of animals, and the direct action in the case of plants. The former are induced to react and thus

[80]Thomson, op. cit., pp. 219-220.

[81]Botanic Garden, 1791, Zoonomia, 1794-96; Phytologia, 1800; Temple of Nature, 1802. It is said that Paley's famous "Natural Theology" was written to counteract the influence of the Zoonomia.

[82]Zoonomia, 1st ed., p. 503. Cf. E. Krause: Life of Erasmus Darwin, with a Preliminary Notice by Charles Darwin. 1879.

[83]Hydrogéologie, 1802.

adapt themselves, while the latter, without a nervous system, are moulded directly by their surroundings. And, so Lamarck believed, such bodily modifications—acquired characters—are transmitted to the next generation and bring about the evolution of organisms.[84]

Through the influence of Cuvier, and the relative weakness of Lamarck's successors—the foremost was Etienne Geoffroy-Saint-Hilaire (1772-1844)[85]—the French School of evolutionists dwindled to practical extinction, while in Germany, Goethe (1749-1832), the greatest poet of evolution, and Treviranus (1776-1837) "brilliantly carried the argument without carrying conviction," for the man and the moment must agree. Then in England the uniformitarian ideas of Hutton (1726-1797), elaborated by Lyell (1797-1875) in his "Principles of Geology, being an attempt to explain the former changes of the Earth's surface by reference to causes now in action" (1830-1833), created an epoch in geology. The prevailing doctrine of cataclysms, emphasized among biologists especially by Cuvier, gradually gave place to that of uniformity—an orderly evolution of the Earth—and paved the way for the next logical step—the evolution of the Earth's inhabitants.[86]

It has been truly said that the idea of development saturated the intellectual atmosphere. But intrenched prejudices which hampered the acceptance of evolution in the inorganic world were immeasurably augmented when the world of life was approached, and only an overwhelming amount of scientific evidence, impartially and convincingly presented could carry conviction.[87] This, in part, accounts for the slight influence of the work of the earlier evolutionists, as well as for the reception accorded the evolutionary views expressed anonymously in the Vestiges of the Natural History of Creation[88] by Chambers (1802-1871). The ten editions of this work (1844-1860) created a furor, especially in England, and were opposed alike by biologist and layman.

The case for evolution at the time, as it appeared to the erudite Whewell, is thus summarized in the first edition (1838) of his well known "History of the Inductive Sciences" and reiterated in the third edition (1857): "Not only is the doctrine of the transmutation of species in itself disproved by the best physiological reasonings, but the additional assumptions which are requisite, to enable its advocates to apply it to the explanation of the geological and other phenomena of the earth, are altogether gratuitous and fantastical. Such is the

[84]Philosophie Zoologique, 1809. English trans. by H. Elliot, 1914. Osborn, op. cit., pp. 165-167. A. S. Packard: Lamarck, the Founder of Evolution, 1901.

[85]Philosophie Anatomique, 1818.

[86]J. W. Judd: The Coming of Evolution, 1910.

[87]Cf. A. O. Lovejoy: The Argument for Organic Evolution before "The Origin of Species." Pop. Sci. Monthly, 75, 1909.

[88]A. Ireland: Introduction to the 12th Edition of the "Vestiges," 1884.

judgment to which we are led by the examination of the discussions which have taken place on the subject."[89]

And then appeared the greatest work of Charles Darwin (1809-1882)—the result of twenty years' labor. The Origin of Species (1859) presented a huge amount of data which most reasonably could be explained by assuming the origin of existing species by descent with modifications from others, and also offered as the modus operandi of their origin the theory of "natural selection, or the preservation of favored races in the struggle for life." In Darwin's words: "As many more individuals of each species are born than can possibly survive, and as, consequently, there is frequently recurring struggle for existence, it follows that any being, if it vary however slightly in any manner profitable to itself, under the complex and sometimes varying conditions of life, will have a better chance of surviving, and thus be naturally selected. From the strong principle of inheritance any selected variety will tend to propagate its new and modified form."

Facts and theories had been brought forward before in support of evolution—indeed the theory of natural selection had been suggested before Darwin's time and again independently by Wallace (1822-1913) just as Darwin was completing his long studies preparatory to publication.[90] But the stupendous task of thinking evolution through for the endless realm of living nature remained to be done, and Darwin did it convincingly by his brilliant, scholarly, open-minded, and cautious marshalling and interpreting of data.[91]

It was the combination of the facts and the theory to account for the facts which won the thinking world to organic evolution and "made the old idea current intellectual coin." Darwin supplied the Ariadne thread which led from the maze of transcendental affinity to genetic continuity. Now we know that evolution is a bird's-eye view of the results of heredity since the origin of life and that the facts of inheritance hold the key to the factors of evolution.

Darwin spent the twenty years subsequent to the publication of the Origin of Species, as he had spent the preceding twenty years, in study and research, the results of which appeared in nine additional volumes. Three of these perhaps may be singled out as primarily an elaboration of the "Origin": The Variation of Animals and Plants under Domestication (1868), The Descent of Man (1871) and The Expression of the Emotions (1872). Singly and collectively these volumes are a monu-

[89] 3d Ed., Vol. 3, p. 481.

[90] A. R. Wallace: The Origin of the Theory of Natural Selection. Reply on receiving the Darwin-Wallace medal of the Linnean Society, July, 1908. Pop. Sci. Monthly, Apr. 1909, p. 396. J. Hooker: The First Presentation of the Theory of Natural Selection. Op. cit., p. 402.

[91] Cf. the Darwin Centennial Number of the Pop. Sci. Monthly, April, 1909.

ment to genius and labor. Erasmus Darwin was wont to say that the world is not governed by brilliancy but by energy. His grandson revolutionized biological thought through their combination.

Among Darwin's early converts from the ranks of professional biologists must be mentioned Huxley (1825-1895)[92] and Hooker (1817-1911) in England, Haeckel (1834-1919) and Weismann in Germany, and Gray (1810-1888) in America—men with the courage of their convictions when courage was necessary, whose support did so much for the promulgation of evolutionary ideas.

> "Thoughts that great hearts once broke for, we
> Breathe cheaply in the common air."

Today no representative biologist questions the fact of evolution—"evolution knows only one heresy, the denial of continuity"—though in regard to the factors there is much difference of opinion. It may well be that we shall have reason to depart widely from Darwin's interpretation of the effective principles at work in the origin of species, but withal this will have little influence on his position in the history of biology. The great value which he placed upon facts was exceeded only by his demonstration that this "value is due to their power of guiding the mind to a further discovery of principles." Darwin brought biology into line with the other inductive sciences, recast practically all of its problems, and instituted new ones.

Such, in briefest form, is a survey of the epochs and epoch-makers in biological progress—a mere glance of the biologist into the past "to the mountains whence cometh his strength." Building upon these foundations the biological sciences are developing with amazing rapidity at the present time chiefly through the cumulative influence of an all pervading desire of students of life phenomena to observe nature at work—actually to control and modify biological processes. Today the investigator insists upon interrogating nature experimentally and observing the modus operandi. In a word, the modern biological ideal is to construct an account of the living organism which can be verified by actual observation provided the proper conditions are afforded. Biology has emerged from the phase of development in which the descriptive note was dominant and has become in fact an experimental science.

[92] T. H. Huxley: Darwiniana, Collected Essays, Vol. 2. Life and Letters, edited by his son, 1901.

THE PROGRESS OF SCIENCE

THE LETTERS OF WILLIAM JAMES

Henry James, maintaining in the third generation the literary traditions of a great name, has edited the letters of his father with additional text sufficient to form an adequate biography. When William James died ten years ago, it was remarked in this journal that "his letters would form a volume of surpassing interest, though it may be that they are too personal for publication." The letters now printed are indeed one of the treasures of literature and their intimate character makes vivid a man of such fine distinction that there is no sense of eavesdropping in reading correspondence intended only for a child or for a personal friend.

Mrs. Carlyle accused her husband of writing letters to her with a view to their posthumous publication. The letters of James are as free from any such intention as the biographical notes written by Darwin for his children. They have been selected and edited with care and good judgment. James's life can be read as an open book in which no page need be concealed.

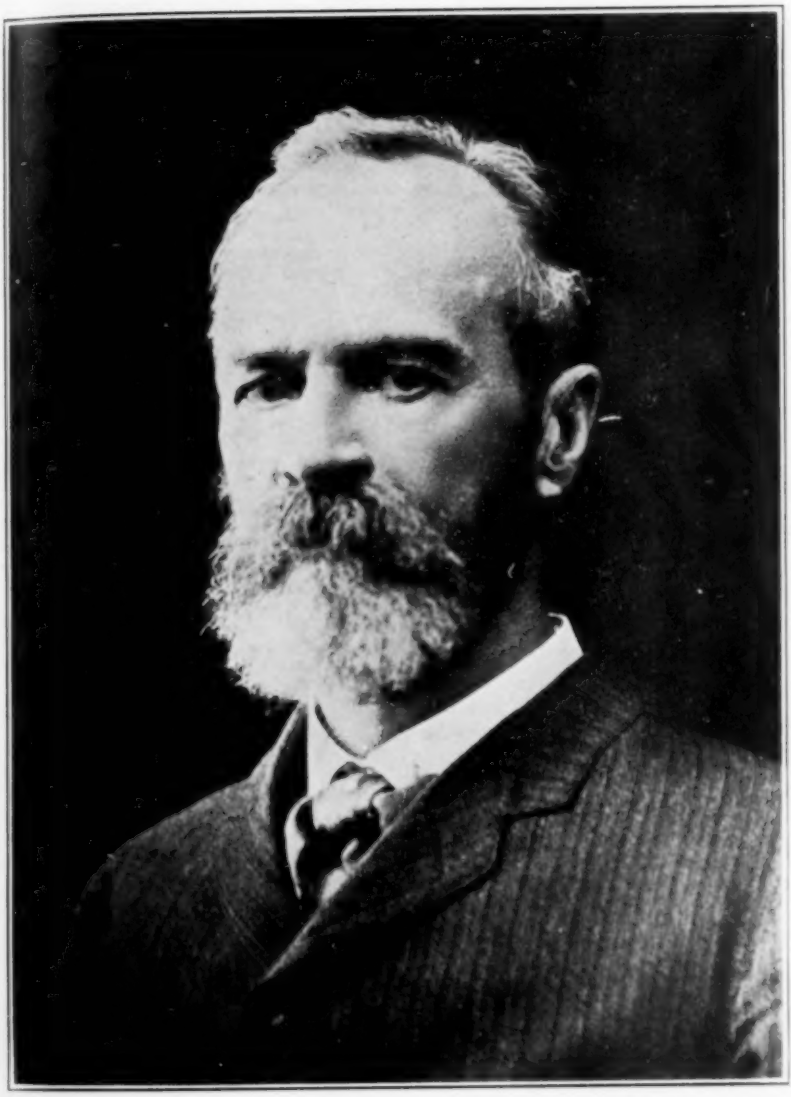
In an unpublished letter, James somewhat pathetically says:

> My whole life seems to consist in doing things to oblige other people, in order to get the field clear to begin my proper work, but every clearing only leads to a new crop of alien duties, so I *never* begin.

The letters show how largely this was true and are themselves a striking instance. James cast his bread prodigally upon the waters; it is fortunate that it has been returned to the world by giving a permanent place in American Literature to letters written in large measure to oblige other people or to fulfill family and personal obligations.

The best notice that can be given to letters of this character is quotations from them, and it may be as well to use those not accessible in the book. There are here reproduced a facsimile of the last page of a letter that shows James's characteristic handwriting and methods, and there is printed in full a letter written at about the same time in 1898, when he was interested in investigations of the medium, Mrs. Piper. It is as follows:

> I herewith return Münsterberg's letter, and the copy of yours to him. I confess I am astonished that he should have made objection to its insertion in the Psych. Rev. It is purely objective criticism and the personalities are all to the point of illustrating the difficulty of keeping practically to his professed point of view about measurement. I can't understand such sensitiveness in one who is himself so sarcastic in his criticisms, and I shall say so to him. Surely The Pschological Review is *the* place for such discussions.
>
> I think you have been unfair to M's article in merely advertising to this dubious epistemological aspect of it. I regretted that he had lugged such a subtlety into the Atlantic. But I rejoiced in any expression from an authority like him which might tend to destroy in the teachers' eyes the prestige of all this industrious mystification to which they are exposed about the immense help which is to come to them from psychological laboratories and measurements. It seems to me arrant bosh and humbug, in the main. Scripture is the loudest voiced sinner, though not the most influential, and he deserves to be sat down on hard. It is the *amount* of their claims, and the utter *unreality* of their tone that are so false. Of course teaching and psychology have got to keep in connexion, and M-g and I, as he says in his letter, keep them in connexion most thoroughly in our teaching of the elementary courses here. But to flourish elementary measurements before the teachers' eyes as his own "ideal" goal seems to me to be little short of criminal. It is following an idol of



WILLIAM JAMES

When I asked Mrs Piper to come to Mrs P. he said: "I am hypnotized, and if I get such results as you relate, I should simply faint away." Other hypnotists I've known have said: "Oh no I should never dream of your having to suffer any unpleasantness." I should never dream of your having to suffer any unpleasantness. I should simply faint away to go to such a place." - I call that real shortsighted kindness for mere pleasantness. However it is what I call the "straight road" (Isa. 40:3)

send it yourself

I note with exquisite gratification your longing words towards psychical research. Continue along that line and you will be saved. will very likely after "passing away" become a "cabinet control" and instruct the younger generation in spiritual things.

"Yours for the truth -

(as we always subscribe ourselves when writing to each other)

Wm James

the cave out of all connexion with real life.

As regards my reply to you, make any rejoinder you think best. I should like to write a short (and strictly objective) report on Hodgson's report for the P. R.'s July number, but I promise in advance to keep dumb about your rejoinder in Science.

Your soul seems much burdened by "psychical research"—I wish there were a better name for it! In the matter of St. Januarius, I thought that one of the Germans of the Marine Zoology Station had published an article about it, corroborating the phenomenon entirely, but explaining it as a periodical growth of bacterial slime which could be imitated artificially. (I wish that my memory were better). It surely is premature to say "so much the worse for the Universe," as you do, apropos of any sort of facts which might come true. It all depends on the *interpretation*. I must say that the "Scientist" mind seems to me to be characterized by as sectarian a spirit as any. And apropos of that, let me correct a misunderstanding which others as well as you have undergone as to the words "soi-disant scientist" once used, I forget where, by me. You supposed me to have meant to deny that the individuals in question were genuine scientists. All I meant was to cast contempt on the word "scientist," for which I have a dislike, though it is evidently doomed to acquire the rights of citizenship. It suggests to me the priggish sectarian view of science, as something *against* religion, *against* sentiment, etc., and I merely meant (I wish I could turn to the passage) to suggest the narrowness of the sort of mind that should delight in *self-styling itself* "scientist," as it proceeded to demolish psychical researchers, and not to imply in the least that all those who rejected psych. R. were spurious scientists (in the good sense of the term).

You probably won't read me to the end.

Yours as ever,

W. J.

The two volumes of "The Letters" have frontispieces showing James at the ages of fifty-three and sixty-five. The photograph here reproduced was taken by the Luxcroft Studio, Fitchburg, Mass., apparently when James was about fifty-five years old.

DINNER IN HONOR OF DR. KEEN

On January 20, 1921, a dinner was tendered to Dr. William Williams Keen, the eminent Philadelphia surgeon, at the Bellevue Stratford Hotel, in Philadelphia, in celebration of his eighty-fourth birthday. Between five and six hundred subscribers, representing all parts of the country, and all of the learned professions, and the fields of diplomacy, industry, finance, and the public services, joined in honoring Dr. Keen. In addition about four hundred ladies listened to the addresses which were followed by a reception.

The presiding officer and toastmaster was Dr. Keen's friend and colleague, Dr. George E. deSchweinitz, professor of ophthalmology in the University of Pennsylvania. The speakers, who dwelt on various phases of the activities of Dr. Keen's distinguished career, had all been closely associated with him in one or more of these fields of work. They were: Dr. J. Chalmers DaCosta, his one-time assistant, now Gross professor of surgery, in the Jefferson Medical College, in which chair he had succeeded Dr. Keen on the retirement of the latter from active teaching; Dr. William H. P. Faunce, president of Brown University, of which institution Dr. Keen is an alumnus, and of which he has been for many years a most active trustee; Dr. William H. Welch, of the Johns Hopkins University, and the Hon. David Jayne Hill, former ambassador to Germany.

The many letters of congratulation to the guest of the evening had been collected and bound in three volumes, and these were presented by Major General M. W. Ireland, surgeon general of the United States Army, who detailed Dr. Keen's connection with the Medical Department of the Army, beginning with his services in the field and in the hospitals during the Civil War, and down to, and including the World War, when he held

DR. W. W. KEEN

a commission as a reserve officer, with the rank of major. A bronze bust, by Samuel Murray, of Dr. Keen in his uniform as an officer of Medical Corps, U. S. Army, was presented to him on behalf of the subscribers to the dinner, by Dr. William J. Taylor, president of the College of Physicians, and for many years his private assistant.

Dr. Keen responded in an admirable address which is printed in the issue of *Science* for February 11.

THE FOREST SERVICE

According to the annual report of Chief Forester W. B. Greeley, the receipts of the National Forests have increased 93 per cent. from 1915 to 1920, while the total appropriations for the Forest Service, exclusive of deficiency fire-fighting funds, has increased only 8 per cent. The receipts for 1920 were 10 per cent. greater than for 1919, and an equal increase for the current fiscal year may be expected, unless too much new business has to be rejected on account of lack of funds and trained employees. The appropriations for the current fiscal year were increased only 3 per cent.

In addition to the actual revenue, according to the report, there is an enormous return to the public through the protection of the 500,000,000,000-odd feet of timber for future use, the protection of the headwaters of innumerable feeders of navigation, irrigation and hydroelectric power and the recreational facilities made available to hundreds of thousands of people. "There will always be national resources not measureable in dollars which in public benefit exceed the receipts paid into the Treasury," the report says.

The purchases aggregated at the close of the fiscal year 1,420,208 acres in the White Mountains and the Southern Appalachians and 12,094 acres in the Ozark Mountains of Arkansas. The original program of acquisition contemplated the purchase of about 1,000,000 acres in the White Mountains and not less than 50,000,000 acres in the Southern Appalachians. Nearly one half the proposed White Mountain area has been acquired, but slower progress has been made in the southern areas.

Further appropriations to carry on the purchase work within the areas have been recommended by the National Forest Reservation Commission. "To leave these Eastern forests in their present half finished condition would subject them to formidable fire hazards and other difficulties of management."

There is need also for some action to reduce the danger to the National Forests from the 24,267,723 acres of private lands that are intermingled with land belonging to the government. Most of this land is forested and its misuse, mismanagement and neglect jeopardize the government's holdings. General legislation is urged to acquire the private land by purchase or exchange.

The 1919 fire season was unusually severe and long drawn out, the report states. It was the third successive year of severe drought in the northwest, and the worst of the three. Fires began to occur before much of the customary work of preparation had been done, and this imposed a further handicap upon the forest force, which had been depleted by the loss of many experienced men. The total number of forest fires in the National Forests was 6,800, or 1,227 greater than in the previous year. The area of National Forest lands burned over was 2,030,034 acres, the estimated damage was $4,919,769, and the total cost of fire fighting was $3,039,615.

SCIENTIFIC ITEMS

We record with regret the death of William Thompson Sedgwick, professor of biology in the Massachusetts Institute of Technology since

1883; of Mary Watson Whitney, professor of astronomy emeritus, and from 1889 to 1910 director of the observatory of Vassar College; of Lincoln Ware Riddle, assistant professor of cryptogamic botany in Harvard University and associate curator of the Farlow Herbarium of Cryptogamic botany; of Sir Lazarus Fletcher, keeper of minerals in the British Natural History Museum from 1880 to 1909 and then director of the museum until 1919; and of Dr. Wilhelm Foerster, professor of astronomy at the University of Berlin, at one time director of the Observatory.

Dr. Wallace Walter Atwood, lately professor of physiography at Harvard University, was inaugurated as president of Clarke University, on February 1.

Dr. J. Norris Russell, of Princeton University, has been awarded the gold medal of the Royal Astronomical Society.

The Edison medal, awarded annually for work in electrical engineering by the American Institute of Electrical Engineers, will be presented this year to Dr. M. I. Pupin, professor of electromechanics at Columbia University.

The third half-yearly report on the progress of civil aviation in England by the government, states that regular air services have now been established from London to Paris, Brussels and Amsterdam, and that passenger, mail and goods traffic is increasing. The total number of aeroplane miles flown in the half-year ending September 30, 1920, is nearly 700,000, whilst the aggregate since May, 1919, exceeds 1,000,000. The number of passengers by air exceeds 30,000, whilst the goods carried weigh little less than 90 tons. In value the imported goods exceed £500,000, whilst the exports and re-exports are about half that amount. As part of the mail services, about 50,000 letters have passed each way between London-Paris, Brussels and Amsterdam. The fatal accidents are given as in the ratio of 1 per 50,000 miles flown or per 5,000 passengers carried.